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ИЗМЕРИТЕЛЬНАЯ
ТЕХНИКА

SOVIET INSTRUMENTATION AND
CONTROL TRANSLATION SERIES

Measurement Techniques

(The Soviet Journal *Izmeritel'naya Tekhnika* in English Translation)

■ This translation of a Soviet journal on instrumentation is published as a service to American science and industry. It is sponsored by the Instrument Society of America under a grant in aid from the National Science Foundation with additional assistance from the National Bureau of Standards.

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Publication of *Izmeritel'naya Tekhnika* in English translation started under the present auspices in August, 1959, with Russian issue No. 1 of Jan.-Feb. 1958. The six issues of the 1958 volume year were published in English translation by February, 1960. Russian issue No. 1 of January, 1959 was published in March, 1960, and the twelve issues of 1959 will be published in English translation by December, 1960.

Transliteration of the names of Russian authors follows the system known as the British Standard. This system has recently achieved wide adoption in the United Kingdom, and is being adopted in 1959 by a large number of scientific journals in the United States.

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General: United States and Canada	$25.00
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Instrument Society of America
313 Sixth Avenue, Pittsburgh 22, Penna.

Translated and printed by Consultants Bureau Enterprises, Inc.

Number 10—October, 1959

English Translation Published August, 1960

Measurement Techniques

The Soviet Journal Izmeritel'naya Tekhnika in English Translation

Reported circulation of the Russian original 8,000.

Izmeritel'naya Tekhnika is an organ of the Academy of Sciences, USSR

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A SYSTEMATIC IMPROVEMENT IN LABOR PRODUCTIVITY IS THE PRESSING TASK OF THE COMMITTEE'S LOCAL AGENCIES

B. L. Sokolov

It is noted in the 21st CPSU Congress decisions that one of the most important tasks of the Seven-Year Plan is a substantial improvement in the productivity of labor. This decision fully applies to the State Inspection Laboratories of Measuring Equipment which are faced with problems of labor productivity, the full use of reserves, and overlooked possibilities in utilizing more efficiently the operative personnel's working time, all of them requiring immediate solutions, in view of the fact that the decisions of the 21st Party Congress and those of the June Plenum of the CPSU Central Committee must be carried out in the laboratories without an appreciable increase in the existing operative personnel.

It is at present advisable to introduce a change in the organizational structure of the inspection laboratories. Many laboratories have retained the old internal subdivisions in all the spheres of measurements. Such an organizational structure obliges the leader of each group to spend some of his working time on administrative and organizational problems, even if his group consists of 3-5 people only. It is necessary to decrease the number of subdivisions inside the laboratories and merge two or three groups into one, with a senior engineer in charge of it. Larger groups provide the personnel with greater flexibility in their work and the leader with an easier problem in distributing his forces; workers of such groups obtain the opportunity of mastering related specialities in instrument testing, thus advancing towards the required universality. Finally, the merging of small groups frees their former leaders of any administrative functions, thus making them entirely available for production work. Some of the inspection laboratories, having carried out such reorganization, have become convinced of its beneficial effects on the fulfillment of the planned targets, increased skill of the personnel, and improvement of labor productivity.

In a number of laboratories there still exist separate inspectorate groups. The segregation of these groups has bad effects on the general inspection work, since their personnel is divorced from routine testing and loses its skill through lack of practice. In inspectorate groups people are often employed who are unsuitable for testing work and unfamiliar with testing techniques. Moreover, the skilled personnel of these groups is often too small for general inspection of large plants with diverse and complex measuring equipment, thus leading to inspection at a low technical level.

Workers of the inspectorate groups often duplicate the work of state inspectors by establishing temporary branches in localities and inspecting the areas which had only recently temporary inspection branches established in them by state inspectors. It is necessary to end the segregation of the inspectorate groups in the laboratories, and distribute their personnel among other groups, so that for any general inspection, whether it is a trading establishment or a metallurgical combine, specialists with the required training can be allocated for inspection from among the groups' personnel, and highly skilled specialists sent for the general inspection of large industrial establishments. This measure will have a beneficial effect on the wastage of labor time and the productivity of labor of the laboratory operative personnel.

It is instructive to quote the experience of the Gor'kii State Inspection Laboratory, which tackled the problem of labor productivity and investigated the reason for inefficient utilization of the working time.

On the basis of the 1958 report, it was pointed out to the laboratory that the production per head of its operative personnel was low, and it was suggested that it was due to the bad organization of labor and excessive internal divisions, which prevented the leaders of the groups from directly participating in the routine work.

The laboratory personnel examined the possible ways of raising labor productivity and adopted the following measures. The number of internal groups was reduced by three and it is contemplated to abolish yet another group. The size of the newly established groups is of the order of 10-16 people. The workers of the inspectorate group were transferred to the testing groups. Energetic individuals with initiative and suitable qualifications for technical and organizational leadership were placed at the head of each group. In addition to supervising work, the heads of groups participate in the testing and inspection work.

The supervision of departmental inspection agencies, which was previously segregated, was also transferred to test groups, and it is now being carried out in conjunction with requests for instrument repairs at the same or neighboring plants. This measure provides considerable savings in the inspectors' time and travelling expenses in view of the existence in the Gor'kii region of 44 establishments with 204 measuring equipment inspection agencies. The laboratory has strengthened the control over a rational and full utilization of each operative worker's time. At the production conference the workers of the Gor'kii laboratory made other useful suggestions for an even more efficient use of the operative worker's time and greater labor productivity. All these measures provided in the first quarter of their application an increase of 21% in the production of each operative worker.

Great opportunities for raising labor productivity exist during the operation of temporary branches for checking measures and measuring instruments in the localities.

The laboratory workers of the Russian Federation operate annually over 2000 temporary branches, spending in them over 75,000 man-days. It is obvious that an efficient utilization of the state inspectors' time would have a beneficial effect on the general productivity of labor, and would in turn make it possible to use them in other laboratory work by reducing the time spent by them in the localities.

However, the organization and operation of temporary branches suffer to date from many defects, which lead to a low laboratory productivity, inefficient utilization of the inspectors' time and, in many instances, to an unsatisfactory state inspection owing to lack of supervision of the temporary branches by the laboratory administration.

In order to raise labor productivity and improve the quality of state inspection, the personnel and administration of inspection laboratories should take energetic measures for a better organizaton of the work of temporary branches. Tentative schedules for the operation of temporary branches should be discontinued; they should be fixed on the basis of previous experience in such a manner as to encourage the state inspectors to carry out productive and high-quality work. The supervision of the quality of inspection in these branches and proper utilization of the inspectors' time should be increased.

At the same time, inspectors who carry out high-quality work in the localities and reduce the time spent on it should be commended. The experience and methods of work of such inspectors should be studied in every laboratory and given wide publicity. The report of the work carried out in temporary branches should be examined at production conferences of the laboratories and evaluated according to their results.

Often state inspectors spend two or three days on their return from the districts on compiling an operation and financial report. Such a waste of time should be immediately stopped and the inspectors instructed to prepare their reports during the operation of the temporary branches, so that on their return they would only have to compile the final summaries in the minimum of time.

Mobile inspection laboratories play an important part in raising the labor productivity in local inspections. The use of auto transport in local inspection, with a few exceptions, is still far from being efficient. A rational use of auto transport combining testing and inspection work shortens considerably the operation of temporary branches and leads to high-quality state inspection.

The curtailment and elimination of some of the cumbersome and unwanted accountancy will lead to greater labor productivity in the inspection laboratories and permanent district branches. The writing of reports by test groups of the laboratories should be reduced to the minimum; the registration of technical statements, certificates, inspection documents, etc., should not be done by test groups. Any work of that nature should be carried out by clerical workers in the laboratories and by the receivers of the instruments.

Many heads of laboratories who have on their staff clerical workers, demand that leaders of permanent district branches compile financial and operational reports and keep accounts. As the result of these unreasonable

demands, the senior engineer in charge of a district branch, instead of being a technical worker, becomes essentially an administrator and accountant and cannot devote his time to inspection work. Heads of laboratories should free the engineers in charge of district branches from such unsuitable work, and let the branches keep current account of state collections only. All the remaining operations should be carried out by accountants and economists at the inspection laboratories.

It is important for state inspectors to combine specialities, i.e., to have a knowledge of instruments in several spheres of measurements. This condition will provide the possibility of sending to a factory one inspector to inspect and test instead of several specialists. Therefore, technical courses in the laboratories and permanent branches should provide the opportunity for state inspectors to acquire skill in new methods of testing and studying related specialities. The experience of the Kaliningrad, Kaluga and other inspection laboratories shows the expediency of such measures.

Rationalization of work, especially of labor-consuming processes leads to greater labor productivity. Many laboratory workers make suggestions for more efficient and simple ways of testing and introduce them in their own laboratories; these proposals, however, are not given sufficient publicity. It is necessary to organize a wide exchange of experiences in the field of rationalization and inventions, and to encourage the adoption of approved suggestions in all the inspection laboratories and permanent branches.

At the same time the work of the Committee's departments in the practical application of rationalizing suggestions originated by inspection laboratories is lax. For instance, a method for speedier and simpler checking of goods scales, proposed by technical inspector I. S. Krever of the Chernigov State Inspection Laboratory has been under consideration for a long time now.

The introduction of large standard weights into routine laboratory testing of truck and railroad car weigh-bridges, as well as the adoption of motor trucks equipped with weighing apparatus, has been under consideration for a long time.

According to the report of the Stavropol' laborabory, which equipped motor trucks with weighing apparatus and uses half-ton weights, the time required for checking motor truck weigh-bridges has been halved. The rise in labor productivity and enormous saving in time become quite obvious considering that there are 3000 weigh-bridges in the Stavropol' region.

Rapid-action grips (Committee—approved in 1958) for fixing manometers to sleeves of manometric presses for mass-production checking, greatly increases the speed of checking. However, to date no provision has been made for the centralized manufacture of several hundred such grips, and the laboratories are obliged with great difficulties to find ways and means of making them one at a time at a very high cost.

In view of the decisions of the 21st Party Congress and the June Plenum of the CPSU Central Committee on a wide application of new technology, group mechanization and automation of production, and elimination of heavy manual labor in the near future, the adoption of rationalizing suggestions, which make testing easier and quicker and raise labor productivity, has become an urgent matter.

The development of equipment for automatic checking of analytical weights, pointer electrical instruments, and other measuring equipment which arrives in large quantities for checking in inspection laboratories, is still urgently required. It is also necessary to revise certain test instructions in order to eliminate test operations which are not essential. This refers to measuring pulse generators, whose checking takes up 40 to 60 hours, power meters, etc.

Finally, it is necessary to revise the production norms for state inspectors or establish a new method of estimating their work. The prevailing norms which were established in 1955 have become so outdated that they have almost lost any practical value. It is high time to establish rational production norms which would provide a complete and clear estimate of the work of state inspectors and would improve the work of the State Inspection Laboratories.

The personnel of the State Inspection Laboratories of Measuring Equipment should systematically improve the ways and methods of their activity, look for hidden possibilities for all-round improvement of labor productivity and saving of state funds.

Editorial Note. In view of the decisions of the June Plenum of the CPSU Central Committee, special importance is acquired by the automation and mechanization of testing, in whose development the initiative of the State Inspection Laboratory workers can play an important part. With the aim of the widest possible exchange of experience by means of our journal, and utilization of practical achievements which provide increased labor productivity, we beg our readers to send to the editorial board articles on such achievements.

ANALYSIS OF THE MANUFACTURING ERROR OF A DISCRETE-ACTION INTEGRATOR

V. A. Volkonskii, M. A. Gol'dinov, S. M. Kessel'man, and A. S. Nemirovskii

Both analog- and discrete- action integrators are widely used in measuring instruments. The latter are more commonly used. For instance, our industry manufactures differential flow gages with discrete-action integrators only. This is due to the fact that the dynamics of the discrete-action integrator do not depend on the nature of the measured process, since the speed of setting of the integrator components and the time of switching in and out of the cycle do not depend on the nature of variations of the process under test and are determined only by the constructional peculiarities of the integrator. In some of the discrete-action integrators the effort required for their operation is not transmitted to the measuring system of the instrument.

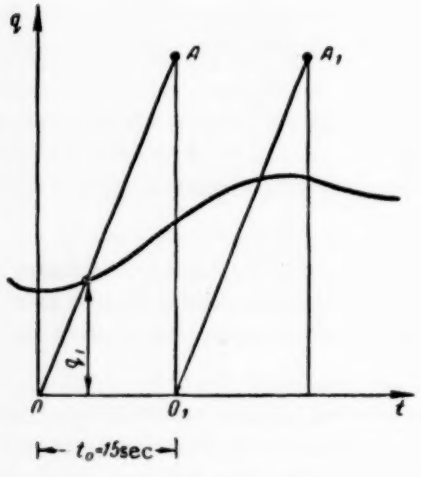

Fig. 1

Descriptions of discrete-action integrators can be found in the literature [1] and in installation and operating instructions of the plants which produce them.

The integrating graph obtained by means of discrete-action integrators is shown in Fig. 1. Here the straight lines OA, O_1A_1, etc., represent the law of movement of the integrator cycle setter, and the curve represents the measured quantity; q_i are the recorded ordinates. Hence it could be said that this graph represents an ordinate "sampling" method. In the integrator made by the Khar'kov plant "KIP" and mounted in secondary type MV instruments, the cycle is set by a synchronous motor, which operates a roller carrier; the integrator of the Moscow plant "Manometr" mounted in secondary instruments type EPID has a synchronous motor with contact rings. The instant of ordinate sampling depends on the angle of rotation of the lever (in the "KIP" integrator) or the brush (in the "Manometr" plant integrator) which is connected to the instrument indicator.

Owing to inaccuracies of manufacture and instability of external conditions, discrete-action integrators work with errors which result in errors of integration. In studying the errors of the discrete-action integrators, it is convenient to divide them into those due to the integrating procedure (discrete integration of a continuous variable), those due to reading (reading off an auxiliary scale, or by means of a digital computer where the error is due to the beginning or the end of integration not coinciding with the instant of the appearance of a digit), and those due to errors in timing the integration cycle (for instance, due to variations in the supply frequency). In addition to the above errors, there also exists the manufacturing error of the integrators.

If a measuring instrument is not connected to an integrator, its manufacturing error will consist in the angle of rotation of the output axle not remaining constant, but varying from cycle to cycle when the input lever, which provides the integrated variable, remains in a fixed position. This error is due to many random causes,

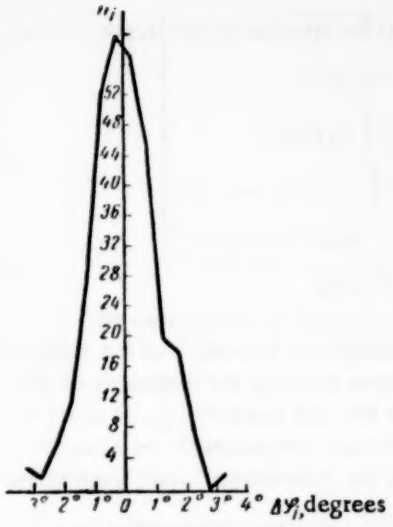

Fig. 2

which affect the delay in the switching in or out of the counter in each cycle of integration. For instance, in the "Manometr" plant integrator the delay is due to the electromagnetic clutch.

The difference between the actual rotation angle φ_i of the integrator output axle and the mean rotation angle φ_{0i} for a large number of cycles with a fixed position of the lever which supplies the integrated variable (the mathematical expectation of the rotation angle) should be known as the manufacturing error of a discrete-action integrator:

$$\Delta\varphi_i = \varphi_i - \varphi_{oi}.$$

Thus, by definition the mathematical expection of this error is zero.*

The corresponding error of the measured variable for one integrating cycle will be

$$\delta_u = \kappa\Delta\varphi, \tag{1}$$

where k is the conversion factor between the rotation angle and the measured variable.

The error of the integrating procedure is a function of the measured variable.

The manufacturing and integration errors do not depend on the measured variable and can be determined experimentally. Results of such experiments and the calculation of the integration error dispersion are the subject of this article.

The integration error corresponding to the time interval (0, T) is

$$\Delta_u = \int_0^T \delta_u(t)\,dt. \tag{2}$$

Since the mathematical expectation of the manufacturing error is $M\delta_u = 0$, the mathematical expectation of the integration error corresponding to these errors is also zero, $M\Delta_u = 0$.

The dispersion of the integration error will be from (2):

$$D\Delta_u = \int_0^T \int_0^T R_u(t, s)\,dtds,$$

where $R_u(t, s) = M[\delta_u(t)\,\delta_u(s)]$ is the correlation function of the manufacturing error.

If the process is assumed to be stationary and ergodic **, as it appears to be from experimental investigations we have:

$$D\Delta_u = \int_0^T \int_{-t}^{T-t} R_u(\tau)\,dt\,d\tau \simeq T\int_{-\infty}^{\infty} R_u(\tau)\,d\tau,$$

* The mathematical expectation becomes distinct from zero due to the angle φ_{0i} and the integrated variable matching inaccuracy which only arises owing to an inadequate connection of the integrator to the instrument, or to an error of the instrument itself.

** The probable characteristics of the manufacturing error, according to the experience gained, do not change with time, hence they are stationary in the broad meaning of the word.

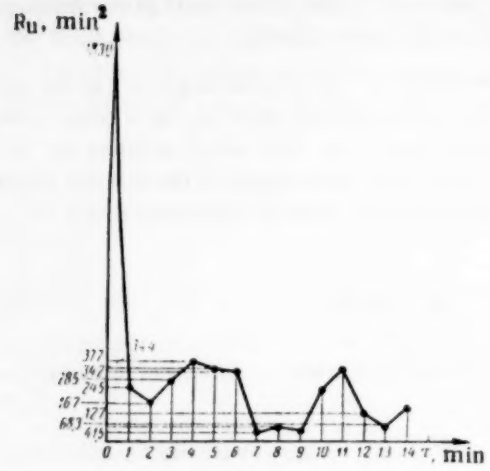

Fig. 3

where $R_u(\tau) = R_u(0,\tau)$. Next by introducing the depth of correlation τ_u which is:

$$\tau_u = \frac{1}{D\delta_u} \int_0^\infty R_u(\tau)\, d\tau, \tag{4}$$

we obtain from (3) and (4)

$$D\Delta_u \simeq 2\, T\tau_u\, D\delta_u. \tag{5}$$

Hence in order to determine the dispersion of the integrating error $D\Delta_u$ it is necessary to know not only the dispersion of the manufacturing error $D\delta_u$, but also the quantity τ_u. In order to find these probable characteristics, integrators of the Khar'kov plant type "KIP" and those of the "Manometr" plant were tested.

The rotation angles of the integrator output axle for a fixed position of the input lever or brush were measured, and discrete values of the manufacturing error were determined

$$\Delta\varphi_i = \varphi_i - \frac{1}{n} \sum_{i=1}^{n} \varphi_i,$$

where n is the number of measurements.

Measurements were made by means of a goniometer with 30" graduations, and equipped with a special attachment for fixing the integrator under test.

During tests the input component of the integrator was placed in a certain position and the integrator was switched in for an operation over one cycle at regular intervals. At the end of each cycle the rotation angle of the integrator output axle was measured.

A large number of measurements were made for several positions of the input component. For instance, in the case of the "KIP" integrator, measurements were made in four positions of the input lever corresponding to φ = 40°, 70°, 100°, and 133°. In each position 80 tests were carried out. On the basis of the data thus obtained:

1. Curves of manufacturing error distribution were plotted for separate series of tests and the whole set of measurements. Figure 2 shows the final error distribution curve of a "Kip" integrator for all the four series of tests*. Tests have shown that the error distribution laws for separate series of tests and the entire set of measurements are very close to each other and approach the normal distribution law.

2. The dispersion of the manufacturing error was calculated from formula:

$$D\Delta\varphi = \Sigma \frac{(\Delta\varphi_i)\, n_i}{n}, \tag{6}$$

where n_i is the number of similar values of $\Delta\varphi$; n is the number of all the measurements recorded.

The value of the manufacturing error dispersion for the "KIP" integrators is $D\Delta\varphi = 0.5\,(\text{degrees})^2$ and for the "Manometr" plant integrators it is $D\Delta\varphi = 58\ (\text{min of the arc})^2$.

3. The correlation relationship graph of the "KIP" integrator for $\varphi_{i\,cp} = 133°$ was calculated and plotted (Fig. 3, the curve of the manufacturing error distribution).

* Such a combination of data for the purpose of plotting a common curve is permissible, since the error in the rotation angle of the output axle is independent of the value of the input signal.

Integrator	Integration time T			
	8 hours	1 hour	20 minutes	4 minutes
Khar'kov plant "KIP"	0.15	0.42	0.73	1.65
"Manometr" plant	0.027	0.077	0.133	0.3

The calculation of the correlation coefficient was made by means of formula

$$R_{\Delta_\tau}\left(\frac{mT}{n}\right)=\frac{\sum_{l=0}^{n-m}\Delta\varphi_l\,\Delta\varphi_{l+m}}{(n-m)\,D\,(\Delta\varphi)}. \tag{7}$$

It will be seen from the graph that the correlation function at mT/ n = 2 min becomes less than 0.15-0.2, i.e., correlation relationships of the manufacturing error are attenuated rapidly.

By using the data thus obtained and formula (5) it becomes easy to calculate the limiting error of integration from the manufacturing error.

It can be shown that with a normal distribution of the manufacturing error, and the integration time considerably larger than the attenuation time of the correlation relationship, the integration error has a distribution law approaching normal distribution. Hence the limiting (referred to the maximum value of integral $q_{max}T$) error can be calculated from formula:

$$\epsilon=\frac{300\sqrt{D\Delta_u}}{q_{max}T}=\frac{300}{q_{max}}\sqrt{\frac{2\tau_u D\delta_u}{T}} \tag{8}$$

(with a probability 0.9973 $|\Delta_u| \le \epsilon\, q_{max}T$).

Let us note that the output-axle turning angle which corresponds to the maximum value of the measured variable is $\varphi_{max} = 130°$, hence:

$$\frac{300}{q_{max}}\sqrt{D\delta_u}=\frac{300}{q_{max}}\sqrt{D\Delta\varphi}=1.8\sqrt{D\Delta\varphi}. \tag{9}$$

From (8) and (9) a table of the values of ϵ in % was calculated for the "KIP" and "Manometr" plant integrators. In the calculations it was assumed that the former has a value of $D\Delta\varphi = 0.5$ (degrees)^2 and the latter $D\Delta\varphi = 0.016$ (degrees)^2 and that both have a value of $\tau_u = 2$ min.

It will be seen from the above that with an integration time greater than 8 hours the integration error under consideration is very small even if the manufacturing error is large.

However, at T = 5-20 minutes, i.e., in checking, it can have an appreciable value.

Without dwelling on the problem of integrator testing it is possible to note that it is advisable to test in such a manner as to be able to determine the systematic and random errors of the transmission part of the instrument with the manufacturing error excluded. This can be achieved by using the data obtained in the study of the latter error and in establishing an optimum condition of measurement (with respect to the number of tests and the duration of each test).

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LINEAR MEASUREMENTS

MEASUREMENTS OF HALF-WIDTHS OF SPECTRAL LINES BY MEANS OF A FABRY-PEROT INTERFEROMETER WITH PHOTOELECTRIC RECORDING

Yu. P. Efremov

Photoelectric recording of the interference fringes in measuring the length of the Fabry-Perot standards opens up wide possibilities for measuring, in addition to the lines of the visible part of the spectrum, lines in its infrared portion [1]. The present work contains measurement results of half-widths of certain lines in the near infrared part of the spectrum, Kr^{86}: λ 7601 A, λ 7854 A, λ 8508 A, λ 8776 A, λ 8928 A, λ 9751 A, which were obtained for the purpose of investigating the possibility of applying these lines to interference measurements of lengths.

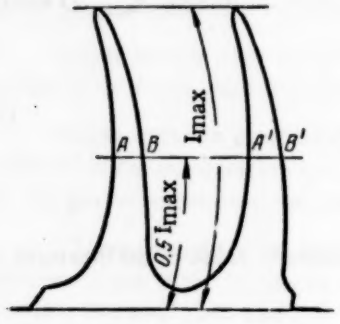

Fig. 1

The measurements of the half-widths of the lines were carried out by means of the same equipment as that used for measuring their wavelengths [2]. The source of light was obtained from a Kösters-Engelgard type radiator with Kr^{86}, excited at the temperature of liquid nitrogen by a dc 10 ma current (current density ≃ 3 ma/ mm^2) [3]. Observations were made across the capillary tube.

Figure 1 shows a recording of two interference maxima of line Kr^{86} λ 8928 A, with a rate difference 2t = 94 mm (amplifier F-17 and recorder N-16).

The observed half-width W of the line can be easily measured: $W = \frac{AB}{A'A} = \frac{A'B'}{A'A}$ in fractions of the order of interference (Fig. 1) or $W = \frac{AB}{A'A}\Delta\nu$ in cm^{-1} if $\Delta\nu = 1/2t$ is expressed in cm^{-1}.

In order to determine the actual half-width ω of the line, it is necessary to know the apparatus half-width a and the relation between the observed W, the apparatus a and the actual ω half-width.

The apparatus half-width for the Fabry-Perot standard is determined (in fractions of the interference pattern) only by the reflection coefficient R of the standard mirrors:

$$a_0 = \frac{1 - R}{\pi\sqrt{R}}. \qquad (1)$$

When the Fabry-Perot interferometer is used with photoelectric recording, the apparatus half-width a also depends on quantity Δ of the recorded portion of the interference pattern (or on the dimensions of the diaphragm which separates that portion) so that $a = a_0$ only when $\Delta \to 0$.

A detailed examination of the manner in which the dimensions of the ring diaphragm, which separates a part of the interference pattern, and the irregularities of the standard plate surface affect the widening of the observed contours of the lines, as compared with the actual lines, has been carried out by Chabbal [4].

It is, however, more convenient to determine experimentally the apparatus half-width a and its relation to quantity Δ. Moreover, an extrapolation for $\Delta \to 0$, i.e., the finding of $a = a_0$ is possible.

TABLE 1

λ(Å)	2l=31 mm		R	2l=94 mm				2l=200 mm				ω	ω/ω_D
	W/Δν	a₀/Δν		Δ₁	a	W	ω'	Δ₁	a	W	ω'		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
5161	0.295	0.286	0.42	0.016	30.5	45.0	25.4	0.032	14.4	36.0	27.0	26.2	1.65
5649	0.280	0.268	0.44	0.016	28.6	37.0	17.5	0.031	13.5	23.2	15.3	16.4	1.36
7601	0.165	0.155	0.62	0.011	16.5	22.6	11.6	0.023	8.0	17.5	13.2	12.4	1.41
7854	0.162	0.151	0.625	0.010	16.1	25.0	14.9	0.022	7.6	16.5	12.8	13.8	1.60
8508	0.142	0.130	0.665	0.009	14.1	22.0	13.2	0.020	6.7	16.0	12.0	12.6	1.57
8776	0.136	0.128	0.675	0.009	13.6	20.5	11.8	0.020	6.5	18.5	14.4	13.1	1.71
8928	0.135	0.128	0.675	0.009	13.6	19.0	10.0	0.020	6.5	16.0	12.0	11.0	1.46
9751	0.132	0.125	0.68	0.008	13.3	17.1	8.0	0.018	6.3	12.5	9.1	8.6	1.24

The effect of irregularities of the plate surfaces leads to an increase in a_0 as compared with its value calculated from (1), and this is equivalent to a decrease in the coefficient R, which is also included in the formula.

It is, for instance, possible to measure a by the contrast of the interference fringes [5]. This method is obviously only applicable in the case of small rate differences when $a \gg \omega$ and hence $a \propto W$.

For large rate differences the values of a and ω are comparable and the calculation of half-width a by means of the contrast becomes inaccurate.

It is better to operate in the following manner.

Let us find an expression for the apparatus half-width in the case when a round diaphragm of radius r is used for separating the recorded part Δ of the interference pattern.

The light flux transmitted by such a diaphragm, placed in the center of the interference rings, is proportional to the integral [6]:

$$\Phi = \int_0^r \frac{x\,dx}{1 + F \sin^2 \pi \left(\epsilon - \frac{tx^2}{\lambda f^2} \right)}. \tag{2}$$

To an accuracy of constant factors this integral is equal to:

$$\Phi = \operatorname{arctg} \sqrt{F+1}\, \operatorname{tg} \epsilon \pi - \operatorname{arctg} \sqrt{F+1}\, \operatorname{tg} (\epsilon - \Delta) \pi, \tag{3}$$

where $F = \frac{4R}{(1-R)^2}$; ϵ is the fraction of the interference pattern in the center of equal slope rings; $\Delta = \frac{tr^2}{\lambda f^2}$ (λ is the wavelength, f is the focal distance of the objective).

It can be easily shown that $\Phi = \Phi_{max} = 2 \tan^{-1} \sqrt{F+1} \tan \frac{\Delta}{2} \pi$ for $\epsilon_{max} = \frac{\Delta}{2}$.

The value of the fractional part of the interference pattern $\epsilon = \gamma$, for which $\Phi = \frac{1}{2} \Phi_{max}$ determines the apparatus half-width a.

Thus we have

$$\operatorname{arctg} \sqrt{F+1}\, \operatorname{tg} \gamma \pi - \operatorname{arctg} \sqrt{F+1}\, \operatorname{tg} (\gamma - \Delta) \pi = \operatorname{arctg} \sqrt{F+1}\, \operatorname{tg} \frac{\Delta}{2} \pi,$$

$$\frac{\operatorname{tg} \gamma \pi - \operatorname{tg} (\gamma - \Delta) \pi}{1 + (F+1) \operatorname{tg} \gamma \pi \operatorname{tg} (\gamma - \Delta) \pi} = \operatorname{tg} \frac{\Delta}{2} \pi.$$

After transformation we obtain

$$\sin \gamma \pi \sin (\gamma - \Delta) \pi = \frac{1}{F},$$

or

$$\gamma (\gamma - \Delta) = \frac{1}{\pi^2 F} = \left(\frac{a_0}{2}\right)^2,$$

whence

$$\gamma_{1,2} = \frac{\Delta}{2} \pm \sqrt{\left(\frac{\Delta}{2}\right)^2 + \left(\frac{a_0}{2}\right)^2}.$$

i.e., $\Phi = \frac{1}{2}\Phi_{max}$ for two values of ϵ separated from ϵ_{max} by $\frac{1}{2}\sqrt{\Delta^2 + a_0^2}$.

Hence

$$a = \sqrt{a_0^2 + \Delta^2} \tag{4}$$

where a_0 is determined from (1).

Let us now examine the case of a square diaphragm used in this work.

The light flux transmitted through a square diaphragm of dimensions h × h, placed in the center of the interference rings, is proportional to the integral:

$$\Phi_1 = \int_0^{h/2} \int_0^{h/2} \frac{dx\,dy}{1 + F \sin^2 \pi \left[\varepsilon - \frac{f(x^2 + y^2)}{\lambda f^2}\right]}. \tag{5}$$

By changing over to polar coordinates ρ and φ, integrating with respect to ρ to an accuracy of the same constant factors for integral (3), we shall obtain the following expression for integral (5)

$$\Phi_1 = \operatorname{arctg} \sqrt{F+1}\, \operatorname{tg} \varepsilon\pi - \frac{4}{\pi} \int_0^{\pi/4} \operatorname{arctg} \sqrt{F+1}\, \operatorname{tg}\left(\varepsilon - \frac{\Delta_1}{\cos^2 \varphi}\right) d\varphi, \tag{6}$$

where $\Delta_1 = \frac{th^2}{4\lambda f^2}$, i.e., $\Delta_r = \Delta$ for a circle inscribed in the square.

An approximate calculation of (6) showed that for $\Delta_1 \leq 0.03$ and $R \leq 0.70$, (6) can be represented with an accuracy of 1% in the form of (3) if it is assumed that $\Delta = 1.27\Delta_1$.

The half-width of the lines were measured by means of standard lengths of 16.5 mm, 47 mm, and 100 mm; and the following relations between the observed W, the actual ω, and the apparatus a half-widths were used [7, 8]:

$$W^2 = a^2 + 2.15\omega^2 \quad \text{for} \quad 0 < \omega < 0.4a, \tag{7}$$
$$W = 0.8a + 0.81\omega \quad \text{for} \quad 0.4a < \omega < 1.5a, \tag{8}$$
$$W = 0.54a + 1.04\omega \quad \text{for} \quad 1.5a < \omega < 4a \tag{9}$$

The measurements results are given in Table 1.

TABLE 2

Radiation	Temperature	ω	ω/ω_D
5461 Å Hg^{198}	18°C	24.9	1.57
ditto	0°	20.0	1.3
6438 Å Cd_{nat}	305°C	34.8	1.4
6438 Å Cd^{114}	250°C	32.5	1.34
5649 Å Kr^{86}	63°K	14.5	1.32
6058 Å Kr^{86}	63°K	13.1	1.2

TABLE 3

λ(A)	7601	7854	8508	8776	8928	9751
V	0.12	0.10	0.20	0.05	0.18	0.35

Column 1 of Table 1 shows the wavelength of the measured lines. For checking purposes half-widths of two lines in the visible spectrum were measured (green Hg^{198} λ 5461 A and yellow-green Kr^{86} λ 5649 A).

Columns 2 and 3 show the values of the observed and apparatus half-widths in fractions of the interference pattern obtained by means of a standard of t = 16.5 mm ($\Delta\nu = 1/2t = 0.303\ cm^{-1}$). In this instance, for all the lines $\omega < 0.4\underline{a}$, and hence the apparatus half-width $\underline{a}$ approaches the observed one W; moreover, the values of Δ used in this instance were sufficiently small ($\Delta_1 < 0.005$) and hence the value of $\underline{a}$ practically coincided with a_0. The values of $a = a_0$ were found from the values of W in the following manner. It was first assumed that $a/\Delta\nu$ = const for all the rate differences and that for 2t = 33 mm a = W. From the known values of $\underline{a}$ and W for rate differences of 2t = 94 mm and 200 mm preliminary values of the lines were determined from (8) and (9). Taking the values of W obtained for 2t = 33 mm and the preliminary values of ω, accurate values of $a = a_0$ were then found from (7).

The apparatus half-widths (columns 6 and 10) for other rate differences were determined from the known values of Δ_1 (columns 5 and 9) and formula (4) in which it was assumed that $\Delta = 1.27\Delta_1$. From the known $\underline{a}$ and W and relations (8) and (9) the half-widths ω' and ω'' were then calculated for 2t = 94 and 200 mm (columns 8 and 12).

The final values of the half-width measurements are given in column 13 as a mean of the values of ω' and ω''.

The half-widths of green line Hg^{198} λ 5461 A and the yellow-green line Kr^{86} λ 5649 A coincide within the measurement accuracy with the data obtained by Terrien [9]. Thus relations (7), (8), and (9) derived for values of $R \geq 0.7$ also hold for lower reflection factors.

Column 4 of Table 1 contains the value of the reflection factor R of the mirrors calculated from (1) on the basis of the data in column 3. A direct measurement of R was made by means of photocell FÉSS for white light only (incandescent lamp) and green light of a mercury lamp: R = 0.57 for white and R = 0.43 for green light. The agreement between the values of R calculated from the experimental determination of the apparatus half-width and those measured directly for λ 5461 A confirms once more the accuracy in determining a_0.

Column 14 of Table 1 gives the ratios of the measured values of the line half-widths to their Doppler half-widths ω_D for T° = 77°K (Kr^{86}) and for T° = 20°C (Hg^{198}).

Table 2 compiled from the data obtained by Terrien [9] also contains some of the ratios of the half-widths of spectral lines to their Doppler half-widths.

As seen from Tables 1 and 2 the investigated infrared lines of Kr^{86} of λ 7854 A and λ 8508 were widened as compared with their Doppler value approximately in the same ratio as the green line Hg^{198} λ 5461 A at the source temperature of T° = 18°C. The widening of line λ 8776 A is comparable to the widening of λ 5461 A at a higher temperature of T° = 20-21°C. The widening of lines λ 8928 A and λ 7601 A is comparable with the widening of the red line of natural cadmium λ 6438 A, and line λ 9751 A is comparable with the widening of the orange line Kr^{86} λ 6058 A at T° = 63°K. It should be assumed, therefore, that the tested infrared lines of Kr^{86} can be used for interference measurements of length with the same justification as the lines of the visible spectrum which are comparable with them in the widening ω/ω_D. The advantage of the infrared lines consists in using them to observe interference patterns at a greater difference rate. Thus the limiting difference rate of line

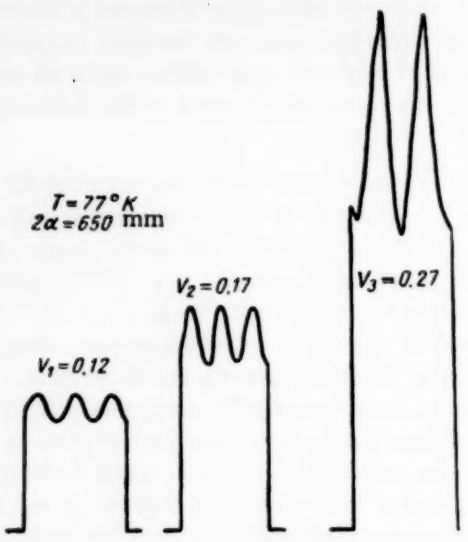

Fig. 2

Kr^{86} λ 7601 A should be equal to $2t_{lim} = 1/\omega \simeq 800$ mm, whereas for the red line of natural cadmium λ 6438 A (its widening ω/ω_D is the same as that of line λ 7601 A) $2t_{lim} \simeq$ ≃ 300 mm.

With a difference rate of 2t = 650 mm the interference fringes were clearly recorded for every one of the six investigated infrared lines.

Table 3 shows the values of the line visibility $V = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$ obtained in this test. The value of Δ_1 was in this instance 3.25 times greater than its value for 2t = 200 mm (see Table 1).

It will be seen from Table 3 that the recorded visibility of the interference fringes is, generally speaking, small. It is, however, possible to raise it artificially by using for the amplification of the photoelectric current a nonlinear amplifier, which would amplify the maximum value of current more than its minimum value. Figure 2 shows a recording of interference fringes for line λ 7601 A, made by means of such an amplifier and a recorder PS1-02. It will be seen that the visibility of fringes rises more rapidly than the magnification.

Moreover, by displacing by some means the value of I_{min} towards the zero line of the chart, it is possible to record interference fringes of the required "visibility."

CONCLUSIONS

The lines of the near infrared region of the spectrum of Kr^{86} can be successfully used for interference measurements of length , especially for difference rates exceeding 500 mm in cases when measurements by means of visible lines of the spectrum become difficult or altogether impossible.

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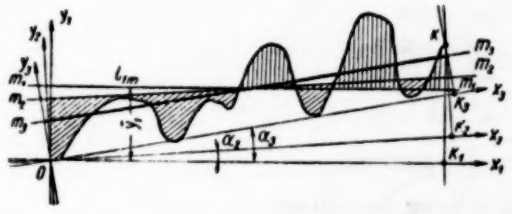
*See English translation.

DETERMINATION OF PARAMETER R_a OF SURFACE ROUGHNESS BY MEANS OF A PLANIMETER

A. N. Kartasheva

GOST 2789-59 specifies as a measure of roughness the arithmetic mean of the absolute distances of the measured profile points to the mean line R_a. In determining R_a from the profilogram recorded on paper by any existing method, it is possible to use a geodetic planimeter. This method reduces the labor spent on determining R_a to 1/2 and 1/3 as compared with its analytical calculation from the profilogram.



In order to be able to determine R_a by means of a planimeter it is necessary to divide the whole profilogram into segments l_i whose lengths corresponds to the chosen base line, and to draw a mean profile line within each segment.

This operation is achieved in the following manner: Let us assume that the segment of the profilogram within whose limits it is required to draw a mean profile line is given in an arbitrary rectangular system of coordinates (x_1, y_1)(see figure). Let us determine by means of the planimeter the area P_1 enclosed by the profile line, the x_1 axis and the perpendicular dropped from point K onto the x_1 axis:

$$P_1 = \int_0^{l_{1m}} y_1(x_1)\, dx_1 \qquad (1)$$

where l_{1m} is the length of the profilogram segment.

The planimeter should be placed in such a position that during the tracing of the contour the angle between its levers should not be too small or too obtuse. When the planimeter is placed into its operating position, it is necessary to record the initial readings of its counters. The contour of the area whose value is to be determined is traced twice, and after each time the readings of the counters are recorded. Then the differences between the readings are calculated. They should not deviate from each other by more than 2-3 digits of the lowest significant figure. In order to determine the area of the traced surface, it is necessary to multiply the arithmetic mean of the two readings obtained by the value of the planimeter graduation.

In order to determine the ordinate $\overline{y_1}$ of straight line m_1-m_1 we use equation:

$$\overline{y_1} = \frac{1}{l_{1m}} \int_0^{l_{1m}} y_1(x_1)\, dx_1. \qquad (2)$$

We now draw straight line m_1-m_1 parallel to the x_1 axis at a distance of $\overline{y_1}$ from it. Straight line m_1-m_1 is the first approximation to the mean line. We now determine by means of the planimeter the area F_1 enclosed by the profile line on one side of line m_1-m_1 and the line itself (this area is hatched vertically). If the system of coordinates is now turned through angle α_2 about point O in the anticlockwise direction, we shall obtain a new system of coordinates (x_2, y_2). By repeating the operations described above we shall obtain area P_2 enclosed by the profile line, the x_2 axis, and the perpendicular dropped from point K onto the x_2 axis. By dividing this area by the length of segment $OK_2 = l_{2m}$, we shall determine the ordinate $\overline{y}_2$ of the straight line m_2-m_2. By drawing line m_2-m_2 parallel to the x_2 axis we obtain the second approximation to the mean line. We now determine the area F_2 enclosed by the profile line and situated on one side of line m_2-m_2 and the line itself (this area is hatched obliquely).

By turning the system of coordinates through angle α_3 we obtain a new system of coordinates (x_3, y_3). In a similar manner we can determine the third position of the mean line m_3-m_3 and area F_3 enclosed by it and the profile line.

$\alpha_1 = 0$	α_2	α_3
F_1	F_2	F_3

Thus we obtain the relation between the angle of slope α and the area F (see table).

The mean line direction which provides the minimum area F is chosen as its final position. By interpolating graphically the angles α we obtain the required value of the mean line angle of slope.

In the above method of determining the position of the mean line by means of the planimeter at least six planimetric measurements are required (three for determining $\bar{y}$ and three for measuring area F).

After the mean lines have been drawn within the area of each segment which corresponds to the base length, we determine by means of the planimeter the areas of the figures enclosed by the mean line and the profile line above (F) and below (F') the mean line.

Parameter R_a is determined from the relation

$$R_a = \frac{F + F'}{l_l}, \tag{4}$$

where l_l is the length of the profilogram segment over which R_a is being determined.

For these operations it is convenient to use the geodetic profilograph PP-2k (MIIZ), which has two counters. When the contour is being traced both counters work simultaneously, thus providing the possibility of raising the accuracy of the area measurement without additional tracing.

The maximum error of this method of determining R_a is, according to the tests we carried out, of the order of 7-10%.

MEASUREMENT OF THE THICKNESS OF LUBRICATION LAYERS

A. A. Kut'kov

Information on the stability of adjacent lubrication layers is not only scarce, but also contradictory. According to some authors, boundary lubrication layers 0.1-0.3 μ thick can withstand large normal loads of the order of 2000 kg-wt/cm^2 and higher [1-3]. Other investigators assert that at as low a load as 4 kg-wt/cm^2 the thickness of the lubrication layer is reduced to 0.022 μ [4].

In this connection the author developed in the Novocherkassk Polytechnical Institute an instrument which determines by means of direct measurements the thickness and strength of the boundary lubrication layers.

The instrument is based on the following consideration: if a metal rod, one end of which is treated as the working surface of the instrument, is placed between two hard plates (Fig. 1a), and a lubricant supplied to the working surfaces, the lubricant will form a layer of a certain thickness (Fig. 1 b) resulting in the straining of the rod. The measurement of the deformation of the rod will provide a measure of the thickness and strength of the lubricant.

The mechanical part of the instrument (Fig. 2) consists of a steel rod, 7, of circular cross section, placed between steel plates, 2 and 10, which are connected by two posts, 6. The touching working surfaces of the rod and plate, 2, are polished to the 14th grade of finish to GOST 2789-51, the mean micro-irregularities not exceeding 0.04 μ. Deviations of the working faces from a flat surface could not be seen in a double microscope. The rod can be initially loaded along its axis by means of screw, 9, which has a micrometer thread and ball bearing, 8.

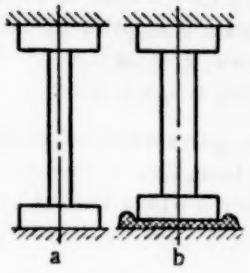


Fig. 1

Screw, 9, is controlled by work gear 11. The maximum vertical displacement required in the experiment does not decouple the worm gear from the micrometer screw. By means of worm gear, 1, and micrometer screw, 3, it is possible to separate the heel of rod, 7, from the working surface of plate, 2. The pressure from the screw to the rod is transmitted through a steel ball, 4. Pump, 14, serves to supply the lubricant under test to the working surfaces of the instrument.

Resistance-type electrical strain gages are used to measure deformations of the thin part of the rod. Transducers R_1 and R_3 which form opposite sides of a bridge are glued to rod, 7, and transducers R_2 and R_4 designed for temperature compensation are glued to post, 15, which is placed alongside the rod. The bridge is balanced by means of a slide wire 17, with transducers

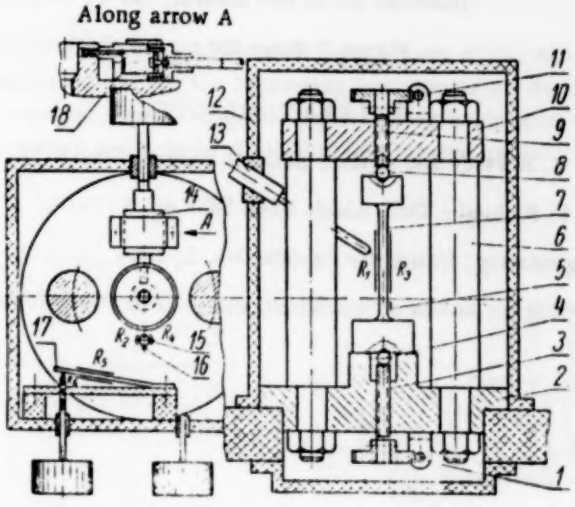


Fig. 2

R_5 and R_6. Transducers R_1, R_2, R_3, and R_4 are 113.3 ohm and 25 mm long, and transducers R_5 and R_6 are 300 ohm.

Before the experiment the measuring part of the instrument is calibrated by straining the rod with known loads. Next the oil container (a recess in the lower plate) and the components of the oil pump are washed out with aviation gasoline. The ends of rod, 7, plate, 2, and screws, 3 and 9, and the ball bearings are washed in gasoline and ethyl alcohol and cleaned with activated carbon. After drying, the components are placed in position by means of tweezers whose ends have also been washed in ethyl alcohol and cleaned in activated carbon. The tank of the oil pump is filled with the lubricant under test, its lid is screwed on, and the pump placed in position. Next the instrument is covered with its lagging, 12, and allowed to stand for a while so that its components will acquire a stable temperature. The temperature under the lagging is checked by means of thermometer, 13, and that of rod, 7, and post, 15, by means of two highly sensitive thermocouples 5 and 16, whose emf is measured on the same milliammeter. A third similar thermocouple is mounted in the oil pump tank 18, and serves to check the temperature of the lubricant. The thermocouples and the thermometer provide temperature variation measurements of ± 0.05°C.

After the temperature has been stabilized, the bridge is balanced by means of the current adjusting device, 17, whose screw knob is mounted outside the lagged container. Next, by turning worm gear, 11, an axial pressure is obtained which must not exceed its critical value derived from Euler's formula. The pointer of the galvanometer should return to zero when the pressure on the rod is raised and returned to normal several times.

Having loaded the rod the third or fourth time to the initial value required by the experiment, the value should be noted and the rod compressed from the other end by means of screws, 3 (whose worm-gear knob is mounted outside the lagged container). The pressure provided by this screw should be sufficient to lift the heel of the rod from its resting surface by 0.3-0.5 μ. Similarly to the previous operation this pressure should be raised

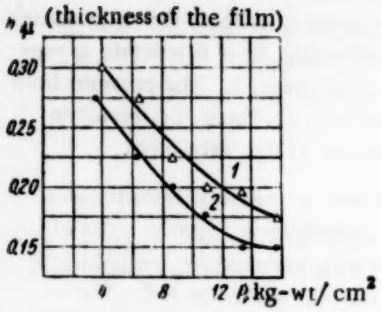


Fig. 3. 1) Commercial oil 45 (machine oil S); 2) commercial oil 20 (spindle oil Z).

and returned to the initial value three or four times with the galvanometer needle returning to its initial deflection. Next after the third or fourth lifting of the heel from its resting surface, the lubricant is supplied by turning the pump handle, and the pressure caused by screw, 3, is rapidly released. After a short time the galvanometer reading is again taken.

The sensitivity of the instrument with a mirror galvanometer GZP-47 GOST 7324-55 was 4 divisions of the scale for 1 kg load, i.e., a stress in the rod of 5 kg/cm^2. The absolute shortening of the rod with a load of 1 kg was equal to 0.1 μ.

The measurement error of the instrument does not exceed 15%.

Tests were made with the following lubricants: commercial oil 45 (machine oil S) and commercial oil 20 (spindle oil Z).

Figure 3 shows the curves obtained on the basis of these tests.

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[4] G. I. Fuks, "Lubricating properties of instrument oils," Collection: Watch Mechanisms [in Russian] No. 1, 1955.

MEASUREMENTS OF MASS

A TRUCK FOR CHECKING TEN-TON SCALES

Ya. I. Keimakh

In fulfilling the decisions of the 21st Party Congress, the personnel of the All-Union Scientific Research Institute of the Committe of Standards, Measures, and Measuring Instruments has developed, in time for the June Plenum of the CPSU Central Committee, a new design for the weighing equipment of the ZIL-151 motor truck which provides mechanized, automatic, and remote controlled loading and unloading of 0.5-ton weights onto ten-ton scales.

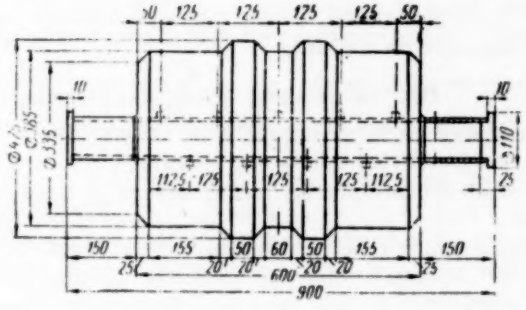

Fig. 1

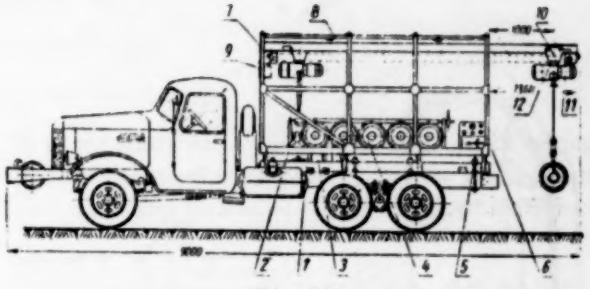

Fig. 2

The main consideration in designing the lifting gear was the necessity of transporting 0.5-ton cylindrical weights 900 mm long with a maximum diameter of 425 mm, rims for rolling and journals for lifting (Fig. 1) on the 4.5 ton motor truck ZIL-151, 8.4 m long, 2.45 m wide, and 3.1 m high.

On the basis of these conditions the construction of the lifting gear was designed as follows.

The body of the truck has a frame (Fig. 2) consisting of welded channel irons No. 10, 8, and 6.5.

The strength and rigidity of the construction provides, with monorails, reliable lifting operations approaching stationary conditions.

The chassis of the truck has two wooden beams fixed to it, which carry the body framework; two monorails (H girders No. 14) are fixed to the upper part of the frame, and protrude 1 m beyond the rear of the truck. Electrically operated 0.5 ton pulleys type TÉP-0.5 run along the monorails. The driving mechanism of the pulley is operated by a 0.4 kw 1440 rpm motor, 9, type AOL-22-4 by means of a magnetic starter and a single-step reduction worm-gear (i = 47, n = 30.5 rpm). Driving sprocket, 7, is fixed to the axle of the worm-gear and operates a motorcycle chain (t = 12.7) which runs over a guiding sprocket, 10, on the motor pulley to sprocket, 11, fixed through a tension adjusting device to the end of the monorail, and then back to motor pulley 12, to which both ends of the chain are fixed. The motor drives the chain through the worm-gear axle with the spindle fixed to it and moves the motor pulley in either direction, according to the pulses transmitted by the operator to the magnetic starter by means of a push button mounted on a control board.

The motor pulley can be placed in any part of the monorail, even if the truck has a slope of 10-15° to the horizontal. The lifting and lowering of weights can be carried out without fearing any slipping of the motor-pulley along the monorail, since the single-step reduction worm-gear and the motorcycle chain, which is tested for a destructive load of 1500 kg, act as reliable brakes.

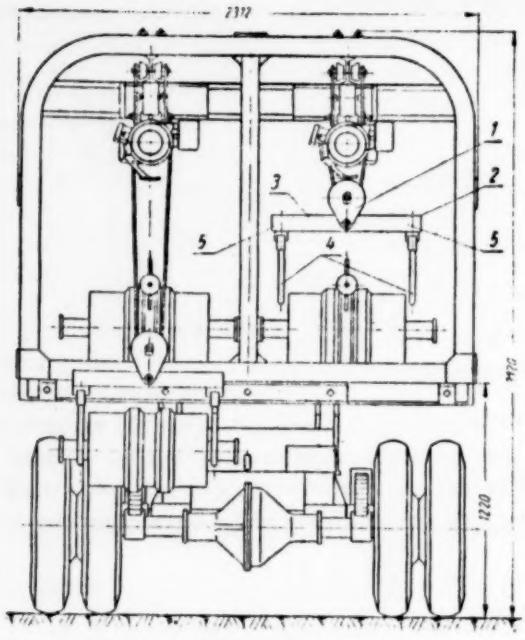

Fig. 3

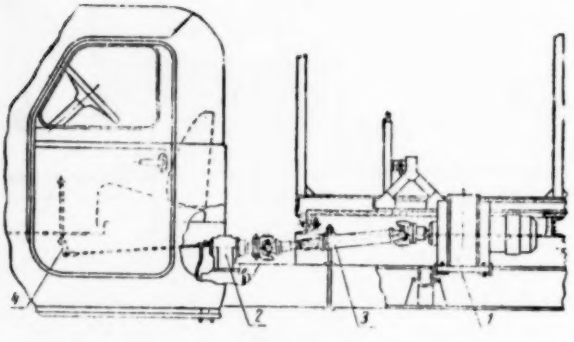

Fig. 4.

Switches, which are mounted at both ends of the monorail disconnect the supply from the driving motor in the two extreme positions of the motor pulley, thus protecting, on the one hand, the motor and on the other, the driving sprocket from a sudden shock.

Instead of a hook, the motor-pulley hanger, 1, (Fig. 3) axle carries a device, 2, for automatic gripping of the weights. This device consists of beam, 3, which is balanced on the hanger axle after final assembly together with its hooks and fixing details and two hooks, 4, suspended from lugs, 5.

The two-way displacement of the beam together with the motor pulley both in the vertical and horizontal directions, the possibility of turning it in the vertical plane with respect to the hanger axle, and the special smooth shape of the hooks, which can be turned in the vertical plane with respect to the lug axle, provide the possibility of bringing the hooks close to the weights' journals and automatically hooking them on by means of push-button controls mounted on a board.

Thus the hooking, lifting, and lowering of the weights in any place inside or outside the truck body can be carried out by one operator from a remote control board placed outside the motor truck.

The height to which the weights are lifted inside the truck is 300 mm and from the weigh-bridge platform it is 1600 mm, the length of the motor pulley travel along the monorail is 4000 mm, the speed of lifting is 8 m/min, and the speed of the pulley movement along the monorail is 12 m/min.

The most vital part of the equipment is the electrical supply unit (Fig. 4) which consists of a 220 v, 1500 rpm generator type BMZ-4.5/4 connected to the truck engine by means of a single-stage, single-speed gear box, 2, type KOM-1 with a gear ratio of i = 1, mounted on the truck distributing box, of a light type Cardan shaft, 3 (from a GAZ-69 automobile) and of mechanism, 4, for controlling the gear box KOM-1.

The generator (3 in Fig. 2) is safely mounted in a cover under the floor of the truck, and serves to supply the two motor pulleys and the two propulsion mechanism motors.

Provision is also made for supplying the motors from commercial three-phase 220 v lines where they exist.

The mechanism for controlling the KOM-1 gear box is worked from the driver's cabin.

Manual adjustment, 5 (Fig. 2), mounted on the control board operates, through a system of pulleys, a flexible transmission, and a pedal and lever mechanism the mixture inlet to the truck engine, serving as a vernier regulator of the generator speed and thus providing a stable 220 v supply from the generator by means of opening or closing the choke shutter of the carburetor.

The control board, 6, is mounted on the rear left-hand side of the truck (Fig. 2) and consists of an enclosed panel with a voltmeter, the generator, 220 v three-phase commercial-supply switch, knife switches for the two motor pulleys, and a light switch for the truck body. The control board also contains a manual mixture inlet control and a flexible armored five-core cable with a push-button control (a switch box) which is connected to the network supplied by the generator, and can be switched over to a three-phase 220 v commercial supply.

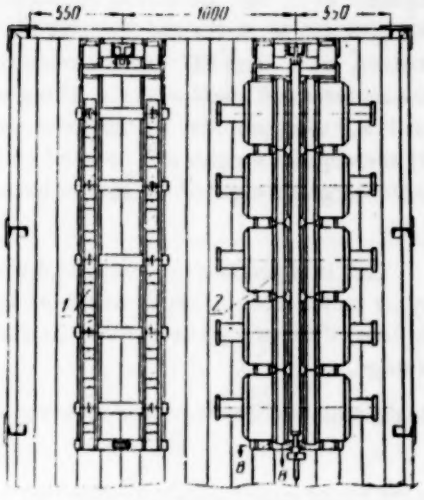

Fig. 5

If the generator needs repairing, the truck supplies can be connected to a commercial three-phase 220 v supply and the generator lifted out of its place by means of the truck motor pulleys.

The starting and stopping of the lifting drive motors and those for horizontal propulsion is carried out by means of reversible magnetic starters, which are mounted in the bodies of the motor-pulleys and at the horizontal propulsion motors.

The equipment for holding ten 0.5-ton weights, 4 (Fig. 2) during transport, at rest, and on inclined surfaces, is mounted in the body of the truck and consists of channel iron No. 10 guide rails, 1 (Fig. 5), wooden beams on which the weights rest, wedge-shaped blocks for holding the weights, and bracing dismountable channel irons, 2. This arrangement provides a reliable fixing of the weights during transportation, makes the weights speedily available for unloading, and avoids the possibility of their side displacement when travelling over bad roads.

The three-ton double axle trailer U2-AP3 is equipped with a similar device for securing weights.

The body framework is covered with a tarpaulin hood, which can be rolled up at the side, thus providing a view of the weights and the operation of the motor-pulleys (Fig. 6).

The body of the truck is lighted inside by means of two 75 w lamps.

The testing of the lifting equipment was carried out in two stages.

In the first stage, bench tests were made in the institute of the static and dynamic properties of the lifting equipment as a whole, of the motor-pulleys with a 25% overload, of the mechanisms controlling the mixture intake and the movement of the motor-pulleys with a longitudinal and transverse incline of the monorail, of the generator drive and the secure fixing of the weights.

The loading and unloading of the six weights onto the trailer was also tested. Tests showed that the protrusion of the monorails is sufficient to provide the loading of the trailer.

The second stage of testing consisted of biweekly test excursions to the places where motor-truck weigh-bridges were located in Moscow and the Moscow region.

It was found in these tests that the weight of the truck with its lifting equipment amounted to 6.7 tons, and together with the set of standard weights to 11.7 tons (10 weights of 0.5 tons each).

The weight-carrying truck can be used in testing the 10-ton weigh-bridges as a tare weight of 6.7 tons, provided standard weights of a total of 1.7 tons are available on the spot, since the total mass of the transported weights only amounts to 5 tons.

If the visited establishments lack a total of 1.7 tons of standard weights, it is possible to use the 3-ton trailer for carrying 6 weights and carry another 8 weights of a total of 4 tons in the body of the 4.5-ton truck in order to reduce its load on 3rd class roads, thus carrying altogether 14 standard weights of a total of 7 tons, and providing the possibility of using the truck itself as a tare load.

Field tests in various establishments showed that the lifting equipment worked satisfactorily, and completely eliminated manual labor in the labor-consuming process of lifting and moving the standard 0.5 ton weights both in the body of the truck and outside it at a distance of the monorail overhang.

The automatic hooking of the weights, and the loading, unloading, and movement of the weights from a push-button control panel outside the truck, considerably raise labor productivity and improve conditions of work, speed up the checking of weigh-bridges to one-third of the time previously required, and reduce the operating personnel to 2 men, i.e., the inspector and the driver.

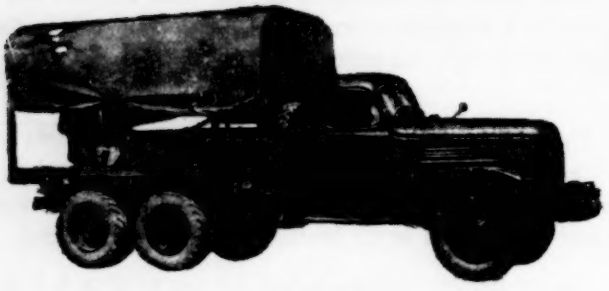

Fig. 6

It should be noted that the weight-carrying equipment built by the Slovak Administration of Weights and Measures and Precious Metals in Bratislava on a Tatra IIIR ten-ton truck (the weight of the motor-truck itself with the lifting equipment is 9.7 tons) provides for the transportation of 71 rectangular weights of a total of 10 tons, with the largest weight of the set not exceeding 200 kg.

Thus it is possible by means of this weight-carrying motor truck to check weigh-bridges up to 20 tons, if the truck itself is used as a tare load without employing a trailer, which constitutes its indisputable advantage.

However, its operation is only partly mechanized, since its single motor-pulley is moved together with the crane beam manually across the truck.

Moreover, the gas engine-driven generator, which supplies the motor pulley and is mounted on a two-wheeled trailer and weighs 315 kg has to be trailed behind the truck as well as a two-wheeled cart used for moving the rectangular weights along the weigh-bridge platform. This weight-carrying truck is served by at least 4 men.

At present our institute is engaged in designing a weight-carrying truck of a greater tonnage and mobility in order to provide greater operational facilities.

Supplying to the State Inspection Laboratories of Measurement Equipment of weight-carrying trucks made to the new design and of appropriate scales for checking the standard 0.5 ton weights will improve the quality and greatly speed up checking of weigh-bridges as it did during the field test of the weight-carrying truck ZIL-151.

AUTOMATIC COMPENSATION OF ELECTROTENSIOMETRIC SCALES

V. I. Zhukovitskii

In recent years resistance strain-gage scales have acquired a wide application. A beam which is strained under the load serves as a transducer in these scales. Resistance wire strain gages which are connected in a bridge

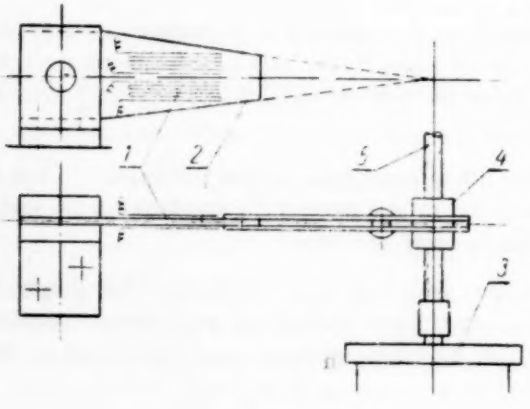

Fig. 1

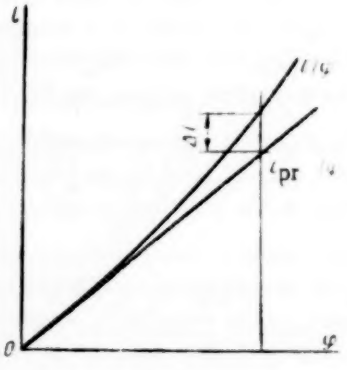

Fig. 2

φ, degree	λ = 0.2			λ = 0,5			λ = 1		
	$\frac{l}{L}$	$\frac{l_{pr}}{L}$	β, %	$\frac{l}{L}$	$\frac{l_{pr}}{L}$	β, %	$\frac{l}{L}$	$\frac{l_{pr}}{L}$	β, %
4	0.06293	0.06283	0.16	0.05244	0.05236	0.15	0.03495	0.03491	0.11
8	0.12646	0.12566	0.64	0.10534	0.10472	0.60	0.07015	0.06981	0.49
12	0.19122	0. 8849	1.44	0.15924	0.15708	1.37	0.10592	0.10472	1.15

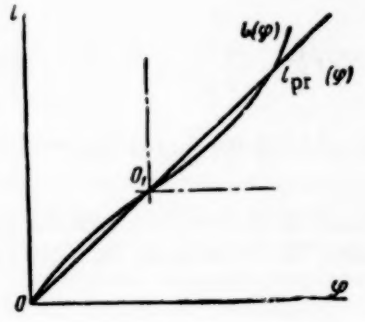

Fig. 3

circuit are glued to the beam. The voltage which appears at the output diagonal of the bridge and is proportional to the weight of the load is usually measured by the compensation method by means of an automatic compensation bridge.

The author of this article has developed an automatic compensator which does not use a slide wire with a sliding contact. The compensator is designed for resistance strain gages but can be used in other measuring circuits.

The compensation-bridge arm resistances consist of wire transducers 1 glued to a small steel beam, 2 (Fig. 1). The beam, which has a constant bending strength, (in the portion where the transducers are glued on) is fixed as a cantilever. Its free end is displaced by a servomechanism, 3, by means of a screw pair. When the beam is bent the resistance of the compensation bridge arms changes.

The variation of the transducer resistance (Δr) is practically proportional to the displacement l of nut, 4, (and hence of the angle of rotation of screw, 5). The small nonlinearity of function $\Delta r(l)$ does not affect the operation of recording or indicating instruments and can be eliminated by an appropriate scale calibration. When the instrument is designed for adding or integrating scales (for instance, for conveyor scales) the nonlinearity will cause measurement errors.

The curved axis of a beam with a constant bending strength represents an arc of a circle with radius ρ. The relative lengthening ϵ of the external layer of the beam is represented by

$$\epsilon = \frac{\delta}{2L_1}\varphi, \tag{1}$$

where δ is the thickness of the beam; L_1 is its length; φ is the angle between the normals to the curved beam axis at its extreme points.

The variation of the strain-gage resistance is:

$$\Delta r = r\epsilon k_T, \tag{2}$$

where r is the initial resistance; k_T is the coefficient of strain gage sensitivity.

From (1) and (2) we have:

$$\Delta r = r\frac{\delta k_T}{2L_1}\varphi. \tag{3}$$

From (3) it is obvious that Δr and φ are related linearly and hence in order to obtain the nonlinear characteristic it is sufficient to find the relation between l and φ. This relation has the form:

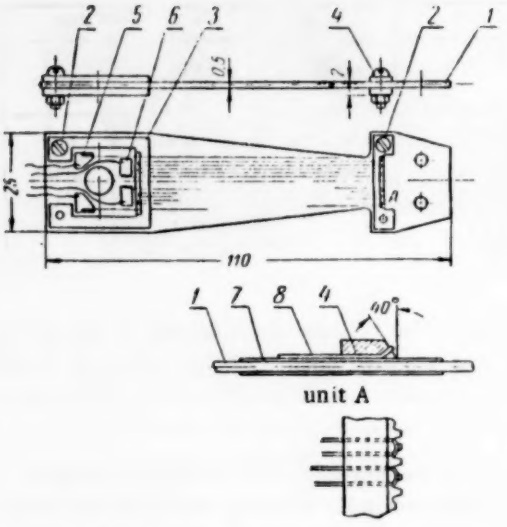

Fig. 4. 1) Beam; 2) screws; 3) and 4) comb formers; 5) end contact; 6) contact; 7) paper; 8) wire.

$$l = L\left[\lambda\frac{\sin^2\frac{\varphi}{2}}{\frac{\varphi}{2}} + \left(1 - \lambda\frac{\sin\varphi}{\varphi}\right)\operatorname{tg}\varphi\right]. \quad (4)$$

where L is the total length of the beam (the sum of the bending and straight parts); and $\lambda = L_1/L$.

The equation of a tangent to this curve at the origin of the coordinates is

$$l_{pr} = L\left(1 - \frac{\lambda}{2}\right)\varphi. \quad (5)$$

A graphic representation of $l(\varphi)$ and $l_{pr}(\varphi)$ is given in Fig. 2.

In order to determine the quantitative deviation of function $l(\varphi)$ from linearity let us calculate the value of

$$\beta = \frac{l(\varphi) - l_{pr}(\varphi)}{l_{pr}(\varphi)}100\% \quad (6)$$

for various values of angle φ and λ.

The results of these calculations are given in the table.

The small nonlinearity can be decreased still further by initially bending the beam towards the negative values of φ and by considering $l_{pr}(\varphi)$ to be a secant, as shown in Fig. 3, instead of a tangent.

When the bridge was tested, its nonlinearity was not noticeable up to an angle of $\varphi = 7°$ (measurements were made with an accuracy of ± 0.2% from the maximum value corresponding to $\varphi = 8°$).

In order to increase the stability and reliability of the compensator the transducer was fixed by means of getinaks • comb formers as shown in Fig. 4, in addition to being glued to the surface. Capacitor paper was first glued on to beam, 1, and then the getinaks comb formers 3 and 4 were fixed to it by means of screws, 2. The 0.03 mm constantan wire was first soldered to the end contact, 5, and wound in loops without crossovers. The ends of the loops were secured on the teeth of the combs. In order to ensure a taut wire, the beam was bent during winding. The end of the first transducer was soldered to contact, 6, and the winding of the second transducer carried on from there. Thus, four similar transducers of 400-600 ohm each were wound on the beam. After winding, the second halves of the comb formers were fastened and the transducers were glued on by glue BF-2. The tightly clamped transducers were then maintained at 150-160°C for 2-3 hours by a thermostat.

Tests of the automatic compensating bridge of this construction showed that it combined comparative simplicity with high accuracy, reliability, and stability of measurements.

• Russian insulating medium – Publisher's note.

MEASUREMENTS OF TEMPERATURE IN HIGH-PRESSURE CHAMBERS BY MEANS OF THERMISTORS

N. P. Grazhdankina, L. I. Domanskaya, and A. K. Kikoin

In measuring temperature in high-pressure chambers it is always necessary to take into account that readings of any temperature measuring device (emf of thermocouples, resistance of resistance thermometers) depend to a certain extent on pressure. It is, therefore, necessary to apply corrections which are obtained experimentally. Thermocouples are most commonly used for measuring the temperature in high-pressure chambers. The pressure characteristics of platinum-platinorhodium, chromel-alumel and copper-constantan thermocouples are known. For the first two thermocouples this relation has been determined experimentally [1] up to a pressure of 4000 kg-wt/ cm^2 and temperature of 600°C. Their emf drops with pressure. For platinum-platinorhodium thermocouples the correction for the above pressure and temperature is 0.25°C and for the chromel-alumel thermocouples it is 1.6°C. For copper-constantan thermocouples the correction for 5000 kg-wt/ cm^2 at 100°C is according to Bridgman [2] equal to 0.28°C. Beyond these limits of pressure and temperature, correction can only be determined by means of special, labor-consuming methods.

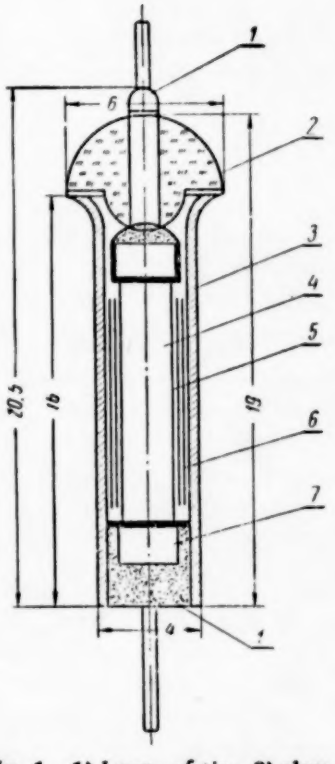

Fig. 1. 1) Layer of tin; 2) glass insulator; 3) protective metallic covering; 4) body of the thermistor; 5) a layer of enamel paint; 6) metal foil; 7) contact caps.

When thermocouples are used for measuring temperature in high-pressure chambers, difficulty is experienced in bringing out the wires from the chamber. Normal designs of lead-out connectors (tapered) involve breaks in the leads. If lead-out connections are used without breaks, it is necessary that parts of the circuit adjoining the lead-out should be at the same temperature as the lead-out, otherwise there arises a "pressure thermocouple," i.e., a thermocouple effect between the compressed and uncompressed metal. Of the lead-out connections known to us the best in this respect is that of M. I. Oleinik [3]. This connection has a "pressure thermocouple" emf according to our measurements of 0.1 μv.

Yet another defect of the thermocouples is the requirement of two leads. The body of the chamber cannot be used instead of the second lead.

The idea of using thermistors instead of thermocouples appears to be very attractive. Their high temperature coefficient makes them suitable for temperature measurements. It is possible to measure with thermistors, providing their parameters are sufficiently stable, temperatures of the order of 0.005°C by means of an ordinary bridge circuit. It is also possible to use one lead when thermistors are employed instead of the two for thermocouples, and the four required for normal resistance thermometers. Finally, the small size and mechanical strength of the thermistors constitute their additional advantages.

In order to be able to use thermistors for measuring temperature in high-pressure chambers, it is necessary to know the effect of pressure on their resistance. Two papers dealing with this question are known to us. In [4] a thermistor of $R_{18°C}$ = 10,000 ohm was measured at pressures up to 150 kg-wt/ cm^2 and temperatures of 0, 25, and 50°C. Its

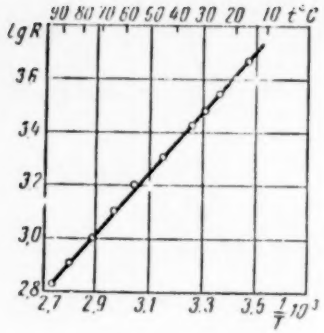

Fig. 2

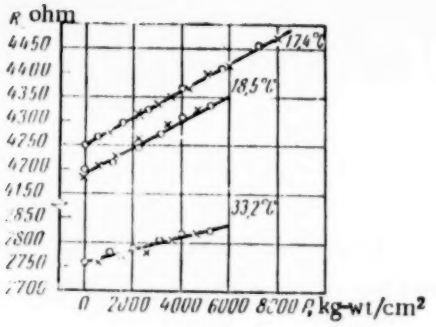

Fig. 3

barometric resistance coefficient was found to be negative and equal to $10^{-6}(\text{kg-wt})^{-1}\cdot\text{cm}^2$, moreover, this coefficient decreases with pressure, approaching zero at the highest pressure used in this investigation. In [5] a disk thermistor with a resistance of 1000 ohm at room temperature was measured at a pressure up to 5000 kg-wt/cm^2 and temperatures of 30 and 70°C. Its barometric resistance coefficient was also negative and equal to $4.6\cdot10^{-6}\cdot(\text{kg-wt})^{-1}\cdot\text{cm}^2$. In the range of temperatures investigated this coefficient was found to be independent of pressure or temperature.

The thermistors made in the Soviet Union have not as yet been measured at high pressures. Hence we undertook to investigate the effect of high pressure on the resistance of one of the types of thermistors produced by our industry with the aim of establishing the possibility of its use for accurate temperature measurements in high-pressure chambers.

We measured two thermistors type MMT-4 (copper-manganese). The test results of both thermistors were identical. Figure 1 shows the construction of the thermistor. For the above-mentioned application of the thermistor, it was necessary to take it apart, i.e., to remove the protective covering, 3, the glass insulator, 2, and the screening foil, 6. Otherwise the thermistor material would not have been subjected to the full test pressure. Figure 2 represents the graph of the relation between log R and 1/T for one of the tested thermistors (R is its resistance and T is its absolute temperature), obtained after dismantling. The curve is represented by the formula:

$$R = Ae^{\frac{B}{T}}$$

where A is a constant depending on the thermistor properties; $B = \Delta E/2k$ (E is the activating energy and k is the Boltzmann constant). The values of B and $\alpha = B/T^2$ obtained from the curve coincided with those provided by the manufacturers. This indicates that the dismantling of the thermistor had not changed its initial properties.

The investigation of the high pressure effect was conducted in two chambers, one of which was large and provided pressures up to 5000 kg-wt/cm^2. This chamber was provided with an obturator carrying four lead-out connections described in [3], so that it was possible to use in it simultaneously a thermistor and a copper-constantan thermocouple for checking the temperature. The other smaller chamber provided pressures up to 8000 kg-wt/cm^2. This chamber was supplied with only one lead-out of the tapered type and organic glass packing. In both chambers the pressure media consisted of a mixture of transformer oil and kerosene. The pressure in the chamber was established by means of a compressor with a multiplier.

In the first chamber the relation of the thermistor resistance to pressure at temperatures of 15.6, 17.3, 18.5, 24.4, 33.2, and 35.2°C, and pressures up to 5000 kg-wt/cm^2 were investigated. In the second chamber tests were made at 17.4°C and pressures up to 8000 kg-wt/cm^2. The resistance of the thermistor was measured on a bridge with an error not exceeding 0.5 ohm. The measuring current flowing through the thermistor was about 0.05 ma. The power of the order of 10^{-2} mw dissipated in the thermistor could not have produced any appreciable heating effect.

Figure 3 shows the relation of the thermistor resistance to pressure at various temperatures. The temperature was strictly controlled only in the large chamber. It was achieved by means of the metal jacket which surrounded

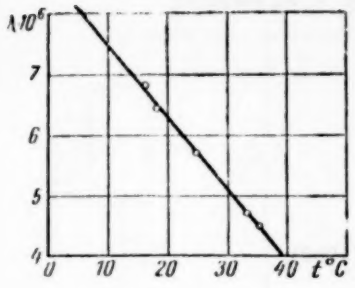

Fig. 4

the chamber and was used for conveying the liquid from Gepler's ultra-thermostat. The temperature was set in 4-5 hour intervals and checked by means of a copper-constantan thermocouple, whose emf was measured on a PPTN-1 potentiometer with a galvanometer which had a sensitivity of $2 \cdot 10^{-7}$ mm/v. Measurements were made 10 minutes after each change in pressure. The time lag was required for dissipating the temperature rise due to compression. After this adjustment the temperature of the thermistor remained constant in the limits of the sensitivity of the measuring apparatus. Changes of resistance with time were not observed, at least during testing intervals up to 30 minutes, and the high thermal inertia of the chamber prevented any random temperature variations. Measurements were

P, kg-wt/cm²	R, ohm	$\frac{\Delta R}{R_0} \cdot 10^2$, %	Δt, °C
1	4186	0	0
1000	4212	0.65	0.22
2000	4241	1.32	0.44
3000	4270	2.00	0.66
4000	4299	2.70	0.88
5000	4328	3.40	1.10
6000	4357	4.10	1.32
7000	4386	4.80	1.54
8000	4415	5.50	1.76

made both with increasing and decreasing pressure. In Fig. 3 points corresponding to the rising and falling pressure runs are distinguished by means of different notations. It will be seen from Fig. 3 that thermistor MMT-4 differs from those investigated in [4] and [5] by the sign of its barometric resistance coefficient. At all the test temperatures the resistance of the thermistor rises linearly with pressure. The relative variation of resistance with the rise of pressure up to 8000 kg-wt/cm² amount to 5.5%. The barometric resistance coefficient is equal to

$$\lambda = \frac{1}{R_0} \cdot \frac{\Delta R}{P},$$

where R_0 is the resistance at atmospheric pressure and P is the pressure; the coefficient changes with temperature according to the curve shown in Fig. 4. The latter phenomenon also distinguishes thermistor MMT-4 from those previously investigated. The barometric coefficient of thermistor MMT-4 is about the same as that of thermistors in [4] and [5] and the range of the tested temperatures varies between $4 \cdot 10^{-6}$ and $7 \cdot 10^{-6}$ $(\text{kg-wt})^{-1} \cdot \text{cm}^2$.

The consistency of results was satisfactory, as proved by repeated measurements in high-pressure chambers. A certain dispersion of points is, however, observable in the rising and falling pressure runs, moreover, in the tests carried out in the large chamber with a maximum pressure of 5000 kg-wt/cm² the dispersion is a little larger than in the small chamber with a maximum of 8000 kg-wt/cm². This effect seems to be due to the greater compression of the thermistor in the small chamber.

These measurements provide the corrections which it is necessary to apply to the thermistor readings. The instability of thermistors under the effect of high pressure produces a dispersion of points on the "resistance–pressure curve" and causes an error which, in our evaluation, is equal to 0.05°C. Corrections calculated from the barometric and temperature resistance coefficients of thermistors together with other data are given in the table.

The table was compiled for a temperature of 18.5°C. However, since with temperature variations both the barometric and temperature resistance coefficients change, these corrections hold for all the temperatures between 15 and 36°C.

It follows from our tests that, owing to the error caused by the thermistor's instability at high pressures, it cannot be considered a more sensitive device than a thermocouple for measuring temperature in high-pressure chambers. The thermistor has the advantage, however, of requiring but one lead-out and a simpler measuring circuit.

The design of the high pressure chambers was developed by M. I. Oleinik and V. A. Stepanov.

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TEMPERATURE MEASUREMENTS IN THE RANGE OF 300-500°C

B. S. Éstrin and P. B. Kantor

In checking mercury-in-glass thermometers above 300°C, the temperature of the medium is measured by means of standard platinum resistance thermometers, and the thermometer reading is obtained indirectly by a compensation method of measurement and calculations from known relations [1].

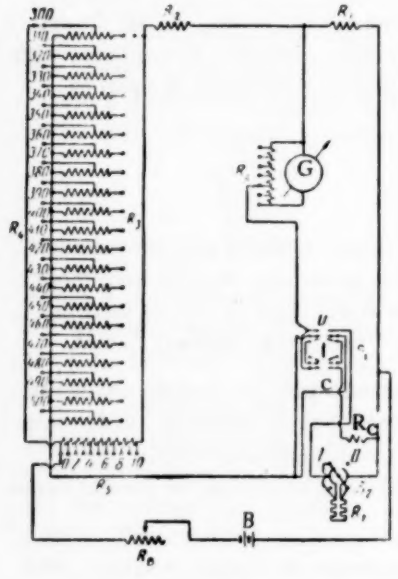

Fig. 1

In order to simplify the checking of industrial thermometers in the temperature range of 300-500°C, The Khar'kov State Institute of Measures and Measuring Instruments developed a design of a single incompletely balanced thermometric bridge, by means of which temperature measurements can be carried out directly in degrees.

The nonlinear relation of the resistance of a platinum resistance thermometer to temperature required the development of a special electrical circuit for the bridge. If the entire temperature range of 300-500°C is divided into intervals of 10° (300-310°, 310-320°, etc.), the relation

$$\frac{R_{(\kappa+n)}-R_{\kappa}}{R_{(\kappa+10)}-R_{\kappa}}=f(t),$$

where k is the number of degrees in multiples of 10° and n is the number of degrees between 1 and 10°, will remain linear in the given range with an error of 10^{-4}°C.

With this in view, a bridge circuit was developed which is shown in Fig. 1 and has resistors R_1 and R_2 as its arms and resistor R_t, the platinum thermometer, as the unknown. The balancing resistance consists of a number of resistance coils R_3 and R_4 connected in pairs and comprising a series of "tens of degrees" and a resistance R_5 making up "units of degrees".

The values of resistors R_3, R_4, and R_5 are chosen in such a manner as to keep R_3 and R_4 constant within each interval of "ten degrees" and make R_5, which shunts R_3, vary the total resistance as the resistance of the platinum thermometer between the temperature of k and k+10°C.

Figure 2 shows the schematic of the bridge for measuring temperature in an interval of 10°C. When the moving contact of resistor R_5 is in position n ($0 < n < 10$) the circuit element consisting of resistors R_3 and R_5 and representing a triangle with sides R_3, R_n, and R_5-R_n, can be converted into a star [3] with rays R_a, R_b, and R_c equal to:

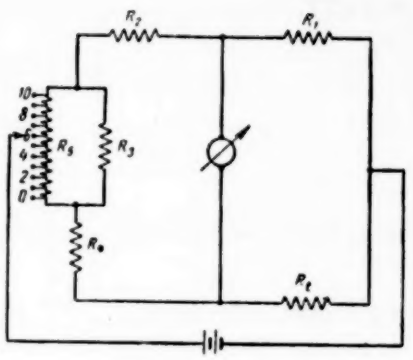

Fig. 2

$$R_a=\frac{R_n(R_5-R_n)}{R_5+R_3};\quad R_b=\frac{(R_5-R_n)R_3}{R_5+R_3};\quad R_c=\frac{R_nR_3}{R_5+R_3}.$$

When the bridge is balanced we have the following relation between resistances:

$$R_1\left(R_4+\frac{R_nR_3}{R_5+R_3}\right)=R_t\left(R_2+\frac{(R_5-R_n)R_3}{R_5+R_3}\right). \tag{1}$$

For n equal to 0 when $R_n = 0$ we have from (1):

$$R_1R_4=R_t\left(R_2+\frac{R_5R_3}{R_5+R_3}\right). \tag{2}$$

For n = 10 when $R_n = R_5$ we have:

$$R_1\left(R_4+\frac{R_5R_3}{R_5+R_3}\right)=R_{(t+10)}\,R_2. \tag{3}$$

Let us now determine from (2) and (3) R_4 and R_3:

$$R_4=\frac{R_tR_2(R_{(t+10)}+R_1)}{R_1(R_t+R_1)}, \tag{4}$$

$$R_3=\frac{R_2R_5(R_{(t+10)}-R_t)}{R_5(R_t+R_1)-R_2(R_{(t+10)}-R_t)}. \tag{5}$$

The values of resistors R_4 and R_3 for all the temperature multiples of 10°C in the range of 300-500°C were calculated from (4) and (5); the value of R_5 was taken as 30 ohm.

The value of resistance R_n was determined from equation (1) for each degree in the range of 400-410°C. The error in the value of a degree thus obtained did not exceed 0.002°C over the entire range of 300-500°C.

Tenths of degree are read from the scale of the mirror galvanometer GPZ-2. In order to keep the value of the galvanometer division constant over the entire range of 300-500°C and its error of measurement below ± 0.02°C the resistance of its shunt R_s is varied. The value of the shunt is varied for every 50°C.

In order to check the constancy of the voltage across the bridge arms a control resistor R_C (Fig. 1) is used and connected instead of the platinum thermometer. The platinum thermometer is connected to the bridge through switch S_2 either by means of four leads connected in pairs (position I) or by means of two leads (position II), thus providing the possibility of correcting for the resistance of the leads, if their resistances are all equal to each other.

The thermometric bridge together with the resistance thermometer can also be used as an instrument for measuring temperatures in the range of 300-500°C with an error of 0.1% of the maximum value, which amounts to 0.5°C.

Editorial Note. The article does not refer to the interchangeability of resistance thermometers. The standard platinum resistance thermometers produced at present are not interchangeable with respect to their calibration and have values of R_0 varying within wide limits of 9.5 to 12.9 ohm.

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A THERMOELECTRIC METHOD OF EVALUATING THE PURITY OF PLATINUM FOR STANDARD THERMOCOUPLES

B. K. Bragin

The stability of calibration of platinum-platinorhodium thermocouples depends to a great extent on the purity of its platinum electrode [1].

The value $W = R_{100}/R_0$, where R_{100} and R_0 are the resistances of platinum wire length at 100 and 0°C, is taken as the criterion of the electrode platinum purity. The quantity W does not measure the percentage of impurities or their composition, but nevertheless provides an indirect indication of the degree of platinum purity.

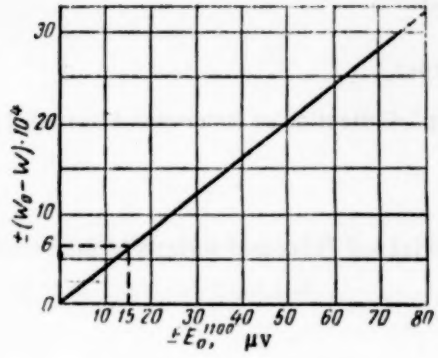
Sample No.	Purity test No.	E_0^{1100}, μV	$\frac{R_{100}}{R_0}$ exp.	$\frac{R_{100}}{R_0}$ calc.
1	"Reference" electrode	0	1.3925	—
2	16	−6	1.3927	1.392_7
3	1604	0	1.3926	1.392_5
4	1606	+2	1.3924	1.392_4
5	1605	+4	1.3924	1.392_3
6	758	+6	1.3923	1.392_3
7	450	+4	1.3922	1.392_3
8	1710	+10	1.3922	1.392_1
9	4610	+12	1.3922	1.392_0
10	1123	+13	1.3921	1.392_0
11	I-51	+14	1.3921	1.391_9
12	1266	+12	1.3920	1.392_0
13	5259	+14	1.3920	1.391_9
14	1122	+14	1.3920	1.391_9
15	332	+15	1.3919	1.391_9
16	5970	+22	1.3915	1.391_6
17	129	+31	1.3915	1.391_3
18	3039	+31	1.3913	1.391_3
19	1058	+44	1.3908	1.390_7
20	331	+42	1.3906	1.390_8
21	1057	+67	1.3897	1.389_8

The thermoelectrode platinum of Soviet production has a minimum permissible value of W equal to about 1.389. Platinum of this quality does not possess a sufficiently stable thermoelectric characteristic at high temperatures, which is probably due to gradual changes in the composition of the metallic impurities. Hence annealing at 1100°C during one hour, as recommended by the International Temperature Scale Regulations for stabilizing the thermal emf of standard thermocouples, does not produce satisfactory results when low quality platinum is used. The raising of the annealing temperature to 1450°C, as practiced by the National Bureau of Standards in the USA [2], lead to an excessive growth of grains in the platinum, to a lowering of its mechanical strength, and hence to a premature wearing out.

According to the operative instruction 161-54 of the Committee of Standards, Measures, and Measuring Instruments [3] the purity of platinum of standard thermocouples must amount to a value of $W \geq 1.391_5$. The thermoelectrode chemically pure platinum brand PL-3 (GOST 8588-57) meets this requirement.

Checking the value of W by means of direct measurements of R_{100} and R_0 requires a considerable expenditure of time, experienced testers, special equipment, and a stock of platinum wire. Therefore, the laboratories which have in their possession either new or used platinum-platinorhodium thermocouples are, in practice, deprived of the possibility of checking the quality of the platinum electrode.

A method for evaluating the value of W free from these defects and sufficiently accurate is based on the fact that the value of W and the thermoelectric properties of platinum are interconnected, since both depend on the purity of the metal.



According to the available data [4] this relation can be represented approximately as being linear and corresponding to a rise of the platinum thermal emf by 2 μv (at a temperature of 1200°C) for a decrease in the value of W of $1 \cdot 10^{-4}$. However, the data on which this relation was based have a considerable dispersion. This circumstance prompted us to conduct a comparison of 20 annealed platinum thermoelectrical wires of Soviet make with a "reference" thermoelectrode made of platinum which had a value of W equal to 1.3925.

The results of the comparison (see table) are represented with sufficient accuracy by equation:

$$W = W_0 - 0.4 \cdot 10^{-4} \cdot E_0^{1100}, \quad (1)$$

where W and W_0 characterize the purity of the tested wire and the "reference" thermoelectrode.

E_0^{1100} is the emf of the tested wire with respect to the "reference" thermoelectrode at a temperature of the operative end of 1100°C and the free end at 0°C.

The differences between the experimental values of W and those obtained by calculation from (1) do not exceed $2 \cdot 10^{-4}$.

Thus, according to our data, a decrease in the value of W of $1 \cdot 10^{-4}$ corresponds to an increase in the thermal emf of platinum of 2.5 μv at 1100°C.

This method of checking the quality of the platinum electrodes entails the use of a "reference" electrode with a known value of W. Such an electrode can be made out of 0.5 mm platinum wire, 1 m long and possessing a $W = R_{100}/R_0$ of not less than 1.392.

The measurement of R_{100} and R_0 should be made on a sample of wire annealed according to the previously mentioned instructions. The sample is connected as a resistance thermometer with a helical frameless sensing element of $R_0 \simeq 0.5$ ohm. Before being measured, the sensing element is treated successively in a 50% solution of KOH and HCl, washed out in water, dried, placed in a clean quartz test tube, and annealed again in a vertical oven at 850°C for four hours.

The total error in determining $W = R_{100}/R_0$ should not exceed 0.01% and the error in measuring temperatures of 100°C and 0°C should not exceed 0.01-0.02°C.

For purposes of stabilization the "reference" element should be annealed at 1100-1150°C* by passing current through it for 1 hour and, in addition, in an oven at 1100°C. The annealing in the oven is carried out after placing the wire inside a single tube of pure porcelain with a 3-4 mm external and a 0.8-1.2 mm internal diameter.

The platinum half of PPO [5] thermocouples can be used successfully as "reference" electrodes. The platinum used in these thermocouples has, according to the technical specifications of the producer plant, a W value of not less than 1.3920.

The determination of thermal emf of a pair of platinum electrodes is carried out according to the method proposed by us earlier for checking thermocouples by comparing similar thermoelectrodes [6]. This method is convenient because it does not require a special experiment and provides an estimate of the platinum electrode quality during the testing of the thermocouple (at 1100° and 1083°C)

The value of W can be calculated from formula (1) or determined by means of the graph (see figure).

CONCLUSIONS

Strict tolerances with respect to the stability of standard thermocouples require the checking of the value of $W = R_{100}/R_0$ of the electrode platinum. Direct measurements of R_{100} and R_0 are complicated and require considerable expenditure of time. The thermoelectric method of indirect determination of R_{100}/R_0 provides a sufficiently accurate and speedy check of this characteristic of the platinum electrode.

* For a wire of diam 0.5 mm the current strength was ~10.3 amp.

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RECORDING OF ELECTRICAL ENERGY CONSUMPTION ON AN OSCILLOGRAM

V. Yu. Chudnovskii

The study of machines employed in power-consuming technological processes has as its object the finding of working conditions which provide the minimum relative expenditure of electrical energy.

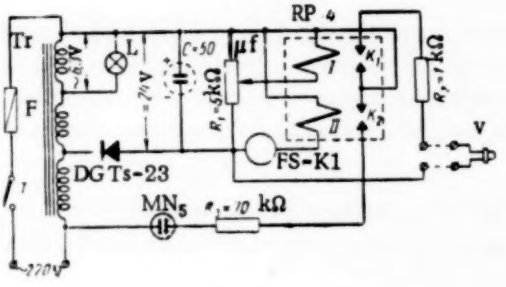


Fig. 1

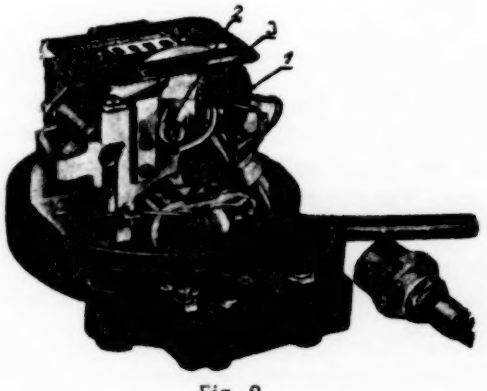


Fig. 2

In these investigations, in addition to recording the efficiency of the machines, and a whole series of kinematic parameters which determine the conditions of its operation, it is also necessary to record the consumption of electrical energy during the operation of the machine.

Normally, this recording is carried out by means of a recording electricity meter or a recording wattmeter. In either case it is difficult to relate these instrument readings with respect to time with other parameters under test, if the latter are recorded on a moving-coil oscillograph.

Moreover, neither a wattmeter nor an electricity meter (under normal conditions) can provide the required accuracy if the load variations are sudden and frequent.

For the experimental study of the work of a large rotor excavator the author of this article has developed and used an apparatus which provides the possibility of recording power consumption in "batches" on an oscillogram over small intervals of time by means of an ordinary electricity meter.

Figure 1 shows the schematic of the equipment.

Transformer Tr, germanium diode DGTs-23, and filter capacitor C comprise a half-wave rectifier which supplies direct current to the windings of the polarized relay RP-4.

Winding I of the relay is supplied with a constant voltage whose value is selected by means of potentiometer R_1. Winding II of the relay is supplied with a voltage from the rectifier through the photoresistor FS-K1. Windings I and II are connected in opposition.

Lamp L serves to illuminate the photoresistor.

Both the photoresistor and the lamp are placed inside the meter under the disk in such a manner that the resistor is only lighted by the beam reflected from the disk. Several radial lines are painted with matte black paint uniformly round the circumference.

Figure 2 shows the position of photoresistor, 1, and illuminating lamp 2, in a single-phase electricity meter SO-2 with its lid removed. The small angular chamber, 3, in which the FS-K1 resistor and the illuminating lamp are mounted serves to direct the light beam.

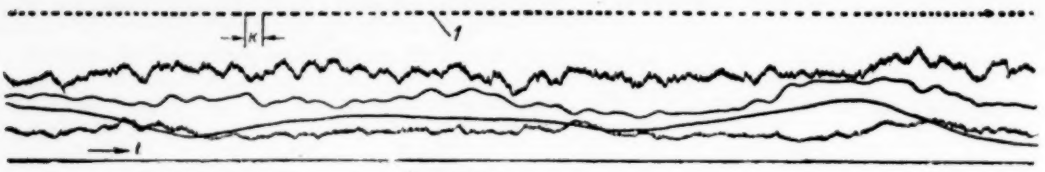


Fig. 3

When the meter disk is rotating, the light beam, which is reflected from the disk surface, falls on the photoresistor. The resistance of FS-K1 drops, the current flowing through winding II rises, and the mmf of this winding becomes larger than that of winding I. The relay operates and closes contact K_2.

When the black portion of the disk passes in front of the photoresistor, its resistance rises and the current flowing through the winding drops. This makes the mmf of winding I larger than that of winding II and releases the relay, thus opening contact K_2 and closing K_1, which are placed in the circuit of vibrator V used as a recorder.

During the operation of the device the vibrator records on the oscillogram dashes whose number over a given time interval is proportional to the speed of the disk and hence the consumption of energy, recorded by the electricity meter during that time.

The adjustment of the polarized relay is simple and is carried out by means of the potentiometer during the operation of the meter. For convenience of tuning the instrument is supplied with a neon lamp MN-5 (Fig. 1), whose circuit is closed by contact K_2. If the position of the potentiometer sliding contact is correctly chosen, the lamp lights when a white portion of the disk passes in front of the photoresistor and extinguishes when a black portion passes in front of it.

Figure 3 shows an oscillogram which was obtained during the testing and records the consumption of the electrical energy by the excavator in the form of dashes, 1, placed in the upper part of the paper; each dash corresponds to a definite amount of energy.

The value of a dash (in kw-hours) is determined from the formula

$$k = \frac{u_T u_V}{aA}$$

where A is the revolution ratio of the meter (the number of turns of the disk for the meter recording of 1kw-hr)—this value is taken from the electricity meter's certificate; a is the number of black marks on the meter disk; u_T is the transformation ratio of the current transformer which feeds the current coil of the meter; u_V is the voltage ratio of the transformer which feeds the voltage coil of the meter. The consumption of the electrical energy during testing is determined from the formula

$$W = kn \text{ (kw-hr)}$$

where n is the number of dashes on the oscillogram during the test period.

This device simplifies considerably the evaluation of the electrical energy consumption during experiments, provides the possibility of analyzing oscillograms to determine the consumption of electrical energy for any required interval of time, and does not produce any errors in the operation of the electricity meter.

A similar device with the polarized relay contact connected to a circuit of a digital counter can serve for remote recording of the electricity meter or tachometer readings. Moreover, contrary to remote transmission by means of mechanical interrupters, the application of this device does not interfere with the operation of the meter by introducing an additional moment of resistance, and thus does not lower the accuracy of its readings.

In theory this device can also be used as a measuring element of self-adjusting automatic control systems, which adjust for optimum conditions on the basis of minimum relative energy consumption.

DETERMINATION OF FREQUENCY CHARACTERISTICS IN DESIGNING AUTOMATIC CONTROL SYSTEMS

A. S. Lifshits and I. A. Dedok

In designing automatic control systems it is often necessary to determine the amplitude and phase-frequency characteristics both of components and systems as a whole.

Several methods of determining the frequency characteristics are known. The most commonly used methods are those of obtaining frequency characteristics by means of loop oscillographs or low frequency cathode-ray oscilloscopes and phase-frequency characteristics by means of phasemeter NF-1.

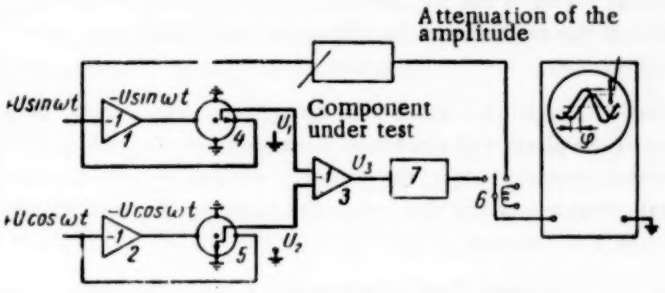


Fig. 1

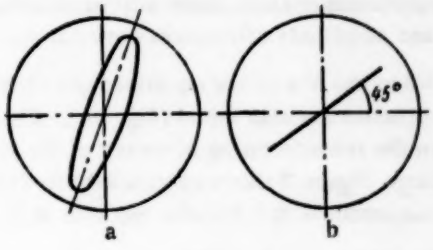


Fig. 2

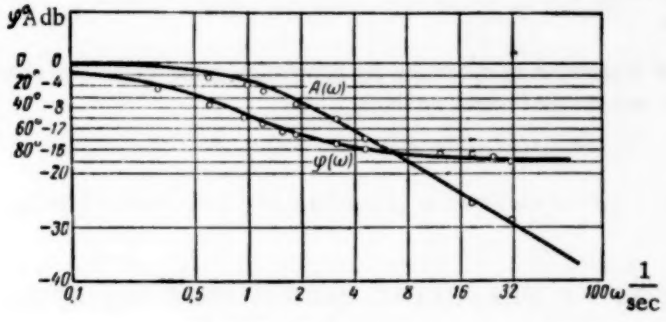


Fig. 3

Each of the above methods has its defects and advantages.

The determination of the frequency characteristics by means of a loop oscillograph is accurate but it involves a considerable expenditure of time in deciphering the oscillograms.

The determination of the frequency characteristics by means of a cathode-ray oscilloscope involves the recording of the amplitude, period, and phase shift of the output signal under test, this leading to considerable expenditure of time and a reduced accuracy of measurement.

Phasemeter NF-1 provides an accurate measurement of the phase, if at the output of the measured component there are no distortions or noise which could lead to false readings.

The use of a phase-shifter and potential-divider in the cathode-ray oscilloscope circuit greatly reduces the measuring time and provides a reading of the phase shift on the scale of the phase-shifter and of the amplitude ratio of the input to the output signal on the potentiometer scale.

The principle of operation of our instrument is based on the comparison of the phase and amplitude of output signal of the component under test with that of the phase-shifter signal.

The phase-shifting circuit consists of normal dc amplifiers type UPT-Ch 1, 2, and 3 and double sine and cosine potentiometers 4 and 5 (Fig. 1).

Potentiometers, 4 and 5, are supplied, respectively, with voltages ± Usin ωt and ± Ucos ωt from a low frequency oscillator.

Voltages $u_1 = U \sin \omega t \cos \varphi$ and $u_2 = U \cos \omega t \sin \varphi$ are fed from the slides of potentiometers 4 and 5, respectively, to amplifier, 3, which adds them.

$$u_3 = u_1 + u_2 = U \sin \omega t \cos \varphi + U \cos \omega t \sin \varphi = U \sin (\omega t + \varphi).$$

The cathode-ray oscilloscope receives voltage u_m from the component under test and that from potentiometer, 7 through chopper, 6.

By adjusting the phase potentiometers, the phase difference between the measured voltage u_m and that from the phase-shifter u_3 is reduced to zero, and by means of the potential divider the amplitudes are equalized.

If the voltage u_3 is fed to the horizontally deflecting plates of the oscilloscope and voltage u_m to the vertically deflecting plates, there will appear on the screen of the oscilloscope an ellipse for the general case of phase and amplitude differences between the voltages (Fig. 2,a).

When the phases are equalized the ellipse becomes a straight line which runs through the origin at 45° when the amplitudes are also equal (Fig. 2b). The accuracy of the phase and amplitude measurements depends in the main on the manufacturing accuracy of the sine and cosine potentiometers, the potential divider, and the accuracy of reading. Figure 3 shows calculated and experimental (dots) frequency characteristics taken by this instrument for a component with a transfer function $W(p) = 1/(1 + pT)$; $T = 1$ second.

It will be seen from Fig. 3 that the experimental and calculated phase characteristics coincide within 1° irrespective of the value of the measured phase.

The frequency range of the tested signal is limited by the range of the vibration converter of 400 cps and amounts to 0-40 cps.

The instrument is reliable in operation for determining the frequency characteristics and can be used for studying commercial automatic control systems.

A SIMPLE METHOD OF MEASURING HIGH-VALUE RESISTORS

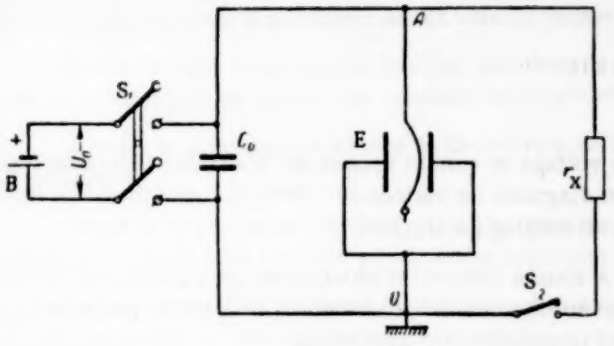
V. I. Ivanov

The measurement of resistance of the order of 10^9 ohm and higher presents certain difficulties due to a number of causes, but mainly to a lack of sensitivity in the measuring instruments used. The requirement of taking into account the resistance of the surrounding insulating materials leads to additional difficulties in actual measurements. Nevertheless high-value resistors are widely used for measuring small currents and also in dosimetric and radiometric instruments. Moreover, the main error in these measurements is due to the inaccuracy of the high-value resistors. In addition, the high-value resistors at present available are very unstable and can change their value considerably depending on the ambient conditions. All these considerations make it very desirable to have a simple and fairly accurate method of measuring high-value resistors.

In connection with the requirement for measuring ionization currents in liquids, we have used the following technique of determining the value of high resistances.

The measured resistor is connected in parallel with electrometer E and capacitor C_0 (see figure).

Let us denote by r_1 the equivalent resistance between points A and O when switch S_2 is closed and switch S_1 open, and by r_2 when both switches are open. Let also $C_1 = C_0 + C_E$, where C_E is the capacitance of the electrometer together with the leads attached to it.



When switch S_1 is closed, capacitance C_1 is charged up to voltage U_0 from battery B. When switch S_1 is opened, capacitance C_1 discharges into the equivalent resistance between points A and O, whose value is determined by switch S_2 being closed or open. Let us examine both cases.

1) Switch S_2 is closed. If time t_1 has elapsed from the instant battery B was disconnected from capacitance C_1, we shall have across it voltage:

$$U_1 = U_0 e^{-\frac{t_1}{r_1 C_1}}. \tag{1}$$

2) Switch S_2 is open. If time t_2 has elapsed from the instant battery B was disconnected from capacitance C_1, we shall have across it voltage:

$$U_2 = U_0 e^{-\frac{t_2}{r_2 C_1}}. \tag{2}$$

It is obvious that

$$r_x = \frac{r_1 r_2}{r_2 - r_1}. \tag{3}$$

By finding r_1 and r_2 from (1) and (2) and substituting their value in (3) we obtain:

$$r_x = \frac{t_1 t_2}{C_1\left(t_2 \ln \frac{U_0}{U_1} - t_1 \ln \frac{U_0}{U_2}\right)}. \tag{4}$$

If we set $t_1 = t_2 = t$ and express t in seconds, C_1 in $\mu\mu f$ and r_X in ohm, we finally obtain:

$$r_x = 10^{12} \cdot \frac{t}{C_1 \ln \frac{U_2}{U_1}}. \tag{5}$$

The value of C_1 in Eq. (5) must be determined by a direct measurement of capacitance between points A and O, which does not present any difficulties. Ratio U_2/U_1 is read off the electrometer scale. Time t and capacitance C_0 are chosen so as not to make ratio U_2/U_1 too large. As an example, let us note that if for a resistance $r_X = 10^{11}$ ohm we make $C_1 = C_0 + C_E = 1000$ $\mu\mu f$, then $t = 100$ sec and $U_2/U_1 = 2.72$ which is very convenient for measurement.

Although theoretically no special requirements need be specified for the capacitor C_0 or the insulation of the leads and connections, in practice it is desirable to aim at making the insulation resistance of the same order or higher than the measured resistance, thus keeping the accuracy of measurement high.

We used for our measurements a string electrometer SG-1M; the voltage of the battery was 200 v, which gave a full scale deflection of the electrometer fiber.

The accuracy of the r_X measurements was in practice determined by the accuracy of measuring C_1.

A DEVICE WITH TWO DEGREES OF FREEDOM FOR MEASURING VECTOR QUANTITIES

L. F. Kulikovskii and P. P. Kemeshis

Measuring instruments which determine directly voltage or current vectors are becoming increasingly popular. By means of these devices it is easy to plot vector diagrams for various ac devices and to obtain directly the locus of a voltage or current vector for a circuit with varying parameters.

A simple instrument which provides a direct plot of a voltage or current vector is of undoubted interest for practical testing and investigation of ac circuits.

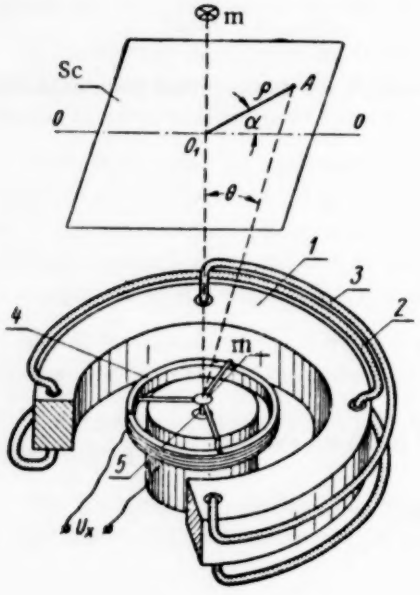


Fig. 1

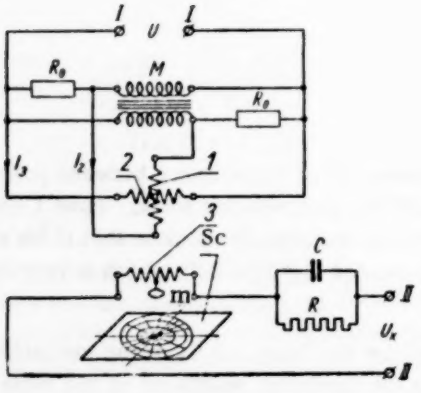


Fig. 2

The basic components of the schematic of a vector measuring instrument (Fig. 1) are a cylindrical core 1 made of blended steel, a two-phase winding 2 and 3, inside the core, and a moving element, 4, which consists of a flat, frameless coil.

The moving element consists of a former which either rests freely on footstep bearing, 5, or is fixed rigidly to a support in the form of an elastic rod connected at one end to the coil and the other to the base of the instrument.

Mirror m is fixed to the center of the coil.

Figure 2 shows the circuit of the vector measuring device.

Winding, 1, is connected to one diagonal of the phase splitting device which consists of a mutual induction M and resistors R_0, and winding 2 is connected to the other diagonal. As the result of this arrangement currents I_2 and I_3, which flow in windings, 1 and 2, have a phase difference of $\pi/2$. The parameters of the phase-splitting circuit are chosen in such a manner as to make the amplitudes of currents I_2 and I_3 equal. Owing to the action of the magnetizing force of the two-phase winding, a rotating field is created around coil, 3.

Since the frame rests on one support it has two degrees of freedom, thus providing the possibility of a simultaneous determination both of the modulus and argument of the measured voltage or current vector.

The frame is connected to the measuring circuit by means of low torque flexible leads.

The recording vectormeter operates in the following manner. In its initial horizontal position, coil 3 has no coupling with the rotating field.

When terminals II–II are connected to the source of the measured voltage $\dot{U}_x$, current $\dot{I}_x$ will flow in the circuit of coil 3. The interaction of this field with the rotating field provides the torque which will incline the axis of coil, 3, to that of the rotating field by a certain angle Θ. Angle Θ is a measure of the modulus of unknown current $\dot{I}_x$.

When the coil is inclined, it will acquire a coupling with the rotating field which will induce in the coil an emf $\dot{E}_3$ tending to balance out voltage $\dot{U}_x$ already present in the coil.

Since in a general case the argument of the emf $\dot{E}_3$ will differ from that of voltage $\dot{U}_x$ a current $\Delta\dot{I}$ will flow in the coil and will correspond to the geometrical difference between $\dot{U}_x$ and $\dot{E}_3$.

Current $\Delta\dot{I}$ will make the coil turn about the axis of the rotating field until the phase angle of the induced emf $\dot{E}_s$ becomes equal to that of the measured voltage $\dot{U}_x$. Then current $\Delta\dot{I}$ will become equal to zero, since the moduli of $\dot{E}_s$ and $\dot{U}_x$ are equal. The coil will attain a balanced condition. The angle of rotation of the coil about its vertical axis is a measure of the voltage vector $\dot{U}_x$ argument.

If coil, 3, rests on a footstep bearing, and there is neither friction nor counteracting torque of leads, the current in the coil will be zero in the balanced condition of the coil.

In order to eliminate reactance in the moving coil circuit, an RC compensating network is connected in series with it.

Mirror m is placed, as previously stated, in the plane of the coil (see Fig. 1). The light beam falling on this mirror is reflected onto scale Sc which serves to project the light at point A.

Radius-vector $\dot{\rho}$ of this point is proportional to angle Θ and is a measure of the modulus of the unknown vector, and angle α between the radius-vector $\dot{\rho}$ and axis O–O determines the unknown argument.

If the deviation of the vectormeter coil is limited to small angles, the coil movement can be represented by equation

$$J\frac{d^2\dot{\Theta}}{dt^2}+\left(P_M+\frac{\Psi^2}{Z}\cos\varphi-j\frac{\Psi^2}{Z}\sin\varphi\right)\frac{d\dot{\Theta}}{dt}+$$
$$+\left(W_M+\frac{\Psi^2}{Z}\omega\sin\varphi+J\frac{\Psi^2}{Z}\omega\cos\varphi\right)\dot{\Theta}=\frac{\Psi}{Z}U_x e^{j(\lambda+\varphi_e-\varphi)}. \quad (1)$$

where U_x is the modulus of the unknown voltage; λ is the argument of this voltage; φ_e is the phase angle of the excitation current; Ψ is the magnetic coupling of the frame; P_M is the mechanical damping coefficient; $\frac{\Psi^2}{Z}\cos\varphi-j\frac{\Psi^2}{Z}\sin\varphi$ is the damping coefficient due to the braking action of the induced current when the coil moves either in the horizontal or vertical direction; φ is the phase angle determined by the coil circuit parameters; W_M is the specific counteracting torque of the leads; Z is the modulus of the coil circuit impedance; $(\Psi^2/Z)\omega\sin\varphi+j(\Psi^2/Z)\omega\cos\varphi$ is the specific electrical torque due to the emf induced in the stationary coil by means of its coupling with the rotating field.

The position of the coil is determined by the vector

$$\dot{\Theta}=\Theta e^{j\alpha}. \quad (2)$$

The modulus of the unknown voltage vector is determined by the deviation angle Θ of the coil, and the unknown argument is determined by the angle of rotation α of the coil.

For convenience of investigation of Eq. (1) let us introduce in it dimensionless parameter k, which represents the ratio of the moduli of the electrical specific counteracting torque and the mechanical specific counteracting torque W_M:

$$k=\frac{\Psi^2\omega}{ZW_M}=P_e\frac{\omega}{W_M},$$

where P_e is the coefficient of the electrical damping.

Considering that the frequency of natural oscillations and the degree of mechanical damping are expressed as:

$$\omega_0^2=\frac{W_M}{J} \quad \& \quad \beta_M=\frac{P_M}{2\sqrt{W_M J}},$$

it is possible to represent Eq. (1) in the form

$$\frac{d^2\dot{\Theta}}{dt}+2\beta_M\omega_0\left(1+\frac{k\omega_0}{2\beta_M\omega}\cos\varphi-j\frac{k\omega_0}{2\beta_M\omega}\sin\varphi\right)\frac{d\dot{\Theta}}{dt}+$$
$$+\omega_0^2(1+k\sin\varphi+jk\cos\varphi)\dot{\Theta}=\dot{\Theta}_i\omega_0^2. \quad (3)$$

where

$$\dot{\Theta}_0=\frac{\psi U_x}{Z W_M} e^{j(\lambda+\varphi}e^{-\varphi)} \tag{4}$$

is a vector which represents the rotation angle of the coil for k = 0.

Equation (3) can be written in the following form:

$$\frac{d^2\dot{\Theta}}{dt^2}+2\beta_M\omega_0\dot{L}\frac{d\dot{\Theta}}{dt}+\omega_0^2\dot{K}\dot{\Theta}=\dot{\Theta}_0\omega_0^2. \tag{5}$$

where

$$\dot{L}=1+q\cos\varphi-jq\sin\varphi=Le^{-j\beta};$$
$$L=\sqrt{1+q^2+2q\cos\varphi};$$
$$q=\frac{\psi^2}{ZP_M}=\frac{P_e}{P_M};$$
$$\dot{K}=1+k\sin\varphi+jk\cos\varphi=Ke^{j\vartheta};$$
$$K=\sqrt{1+k^2+2k\sin\varphi}.$$

In order to determine the parameters of the vectormeter itself, let us solve differential equation (5) by equating the right hand side to zero. Having derived and solved the characteristic equation, let us determine its roots:

$$x_{12}=\omega_0(-\beta e^{-j\beta}\pm Ne^{-j\sigma}), \tag{6}$$

where $\beta = \beta_M L$ and

$$N=\sqrt[4]{\beta^4+K^2-2\beta^2K\cos(\vartheta+2\delta)}.$$

The solution of the differential equation has the form

$$\dot{\Theta}=\dot{c}_1e^{x_1t}+\dot{c}_2e^{x_2t}.$$

The integration constants are determined from the initial conditions for t = 0:

$$\dot{\Theta}=\dot{\Theta}_i;\quad \frac{d\dot{\Theta}}{dt}=0.$$

whence

$$\dot{c}_1=-\dot{\Theta}_i\frac{x_2}{x_1+x_2};\quad \dot{c}_2=\dot{\Theta}_i\frac{x_1}{x_1+x_2}.$$

By substituting the values of the roots and the integration constants into Eq. (7) we obtain an expression for the vectormeter coil movement:

$$\dot{\Theta}=\Theta_i\left\{\frac{1}{2}\left[1+\frac{\beta}{N}e^{j(\sigma-\delta)}\right]e^{\omega_0(-\beta\cos\delta+N\cos\sigma)t}e^{j\omega_0(\beta\sin\delta-N\sin\sigma)t}+\right.$$
$$\left.+\frac{1}{2}\left[1-\frac{\beta}{N}e^{j(\sigma-\delta)}\right]e^{\omega_0(-\beta\cos\delta-N\cos\sigma)t}e^{j\omega_0(\beta\sin\delta+N\sin\sigma)t}\right\}. \tag{8}$$

The resulting displacement of the coil is represented by a sum of two logarithmic spirals.

When the right-hand side of the differential equation exists, i.e., when the coil receives a voltage pulse U_X, the particular solution of the inhomogeneous differential equation will have the form:

$$\dot{\Theta}_c=\Theta e^{j(\alpha-\vartheta)},$$

and its full solution will be

$$\dot{\Theta}=\dot{c}_3 e^{x_1 t}+c_4 e^{x_2 t}+\dot{\Theta}_c.$$

After appropriate operation connected with the determination of the constants of integration, the equation of the coil movement for this case will become:

$$\dot{\Theta}=\dot{\Theta}_c\left[1-\frac{\beta_M}{2}\cdot\frac{L}{N}e^{-m_\varphi^3 M^{Lt}}\operatorname{sh}2\omega_0 Nt\right]. \tag{9}$$

In the case when the voltage applied to the coil has a constant modulus and a variable argument, the solution will be:

$$\dot{\Theta}=\dot{\Theta}_c A e^{j\tau},$$

where A is the coefficient of the modulus distortion for a steady state movement; τ is the shift in the argument for a steady state movement.

The expression for coefficient A and the phase shift τ is rather unwieldy

$$A=\frac{1}{\sqrt{1+4\eta^2\frac{\beta^2}{K^2}+\frac{\eta^4}{K^2}+4\eta\frac{\beta}{K}\sin(\delta+\vartheta)-2\frac{\eta^2}{K}\cos\vartheta-4\eta^3\frac{\beta}{K^2}\sin\delta}}, \tag{10}$$

$$\tau=\frac{1}{\eta}\operatorname{arctg}\frac{2\frac{\beta}{K}\eta\cos(\delta+\vartheta)+\frac{\eta^2}{K}\sin\vartheta}{1+2\frac{\beta}{K}\eta\sin(\delta+\vartheta)-\frac{\eta^2}{K}\cos\vartheta}. \tag{11}$$

Here $\eta=\omega_X/\omega_0$ is the ratio of frequency ω_X of the unknown voltage U_X to the natural frequency ω_0 of the coil.

The equation of the vectormeter scale is derived from the examination of the static condition of the coil when $d^2\dot{\Theta}/dt^2=0$, $d\dot{\Theta}/dt=0$ and Eq. (3) takes the form:

$$\dot{\vartheta}(1+k\sin\varphi+jk\cos\varphi)=\dot{\vartheta}_0;$$

$$\dot{\vartheta}=\vartheta e^{j\alpha}=\frac{\psi U_x}{ZW_M\sqrt{1+k^2+2k\sin\varphi}}e^{j\alpha}; \tag{12}$$

$$\varepsilon=\alpha=\lambda+\varphi_e-\varphi-\vartheta.$$

The deviation Θ of the coil is registered on the screen scale by means of the optical system as a radius vector $\dot{\rho}$:

$$\dot{\rho}=2h\Theta e^{j\alpha},$$

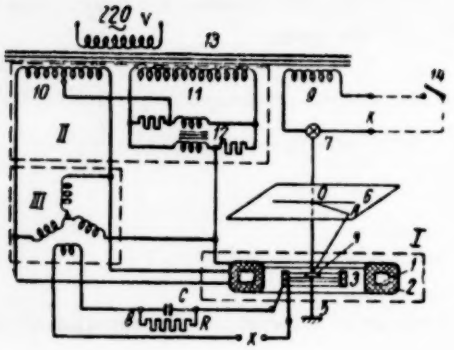


Fig. 3. 1) Toroidal core; 2) toroidal three-phase winding; 3) circular coil; 4) mirror; 5) elastic rod; 6) screen with a coordinate graduation; 7) illuminator; 8) compensating circuit; 9) illuminator supply winding; 10) center-point winding; 11) phase-shifting device supply winding; 12) phase-shifting device; 13) transformer.

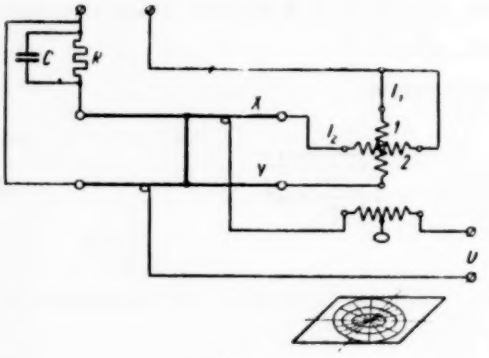


Fig. 4

where h is the distance between the scale and the mirror, or:

$$\dot{\varrho}=2h\frac{\psi U_x}{W_M Z\sqrt{1+k^2+2k\sin\varphi}}e^{j\vartheta}. \qquad (13)$$

It follows from Eq. (13) that the radius vector $\dot{\rho}$ depends not only on the modulus and argument of the unknown voltage, but also on vectormeter coil circuit phase angle φ. Angle φ can be made negligibly small by balancing out the reactance of the coil circuit or by placing an additional resistance in series with it. If the initial value of the argument $\varphi_s-\vartheta$ is assumed to be equal to zero, the vectormeter scale equation becomes:

$$\dot{\varrho}=2h\frac{\psi U_x}{W_M Z}e^{j\vartheta}. \qquad (14)$$

Errors. In order to determine the accuracy of the vectormeter, the basic and additional errors in determining the modulus and argument were analyzed. In addition to the manufacturing, temperature, and frequency errors, the vectormeter in question has specific errors due to the asymmetry of the magnetic field and the instability of the holding torque. The analysis of the errors due to the asymmetry of the magnetic field showed that higher space harmonics of the rotating magnetic field do not produce a torque in the coil of the instrument and thus do not affect the instrument readings. If, however, the magnetic field in the air gap becomes elliptical, errors in determining both the modulus and the argument will arise.

The errors due to the instability of the holding torque can be easily eliminated by keeping the coil circuit impedance constant or by decreasing the electrical counteracting moment to a negligible value.

The static error of a laboratory vectormeter model was found to correspond to that of a grade 2.5 instrument.

Description of the Instrument. The vectormeter with two degrees of freedom [1] was developed and made in the School of Automation and Remote Control of the Kuibyshev Industrial Institute.*

The schematic circuit of the vectormeter is shown in Fig. 3. The basic units of the circuit consist of I - the sensing unit, II - the phase shifter, and III - the electrical corrector.

The electrical corrector serves to compensate the initial emf induced in the frame due to a certain initial coupling.

The RC circuit serves to balance out the reactance of the coil circuit.

The beam of light reflected from the mirror falls on the screen where it marks off the radius vector $\dot{\rho}=\overline{OA}$ by means of a light spot A.

The vectormeter has the following technical characteristics: supply voltage, 220 v; the maximum measured current, 5 ma; the maximum measured voltage, 1.1 v; the resistance of the coil, 200 ohm; distance between the scale and the mirror, 200 mm; and induction in the air gap, 620 gauss.

In order to be able to photograph the locus of the vector a photographic plate holder is provided.

* A vectormeter with two degrees of freedom was exhibited at the All-Union Industrial Exhibition in 1956 and 1957.

This vectormeter is designed to record hodographs of current vectors. The use of the vectormeter for bridge balancing provides a direct indication of the bridge convergence. Its use in conjunction with an ac compensator provides a speedier balancing of the measured voltage. Figure 4 shows the schematic of a rectangular-coordinate ac compensator.

A vectormeter with a two-phase winding was used in this compensator. Windings 1 and 2 are connected in series with slide wires X and Y. Currents I_1 and I_2 displaced by 90° provide a voltage drop on slide wires X and Y and a rotating field in the sensing element of the vectormeter.

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[2] P. P. Kemeshis, "A ferrodynamic polar-coordinate vectormeter with two degrees of freedom," Author's Report of a Dissertation for a Candidate's Degree at the Kaunas Polytechnical Institute, 1957.

EQUAL SENSITIVITY CURVES IN AC BRIDGE CIRCUITS WITH PHASE-SENSITIVE INDICATORS

V. Yu. Kneller

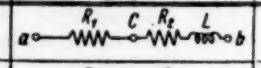
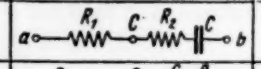
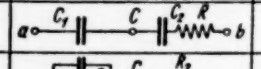
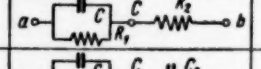
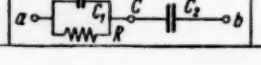
The sensitivity of an ac bridge circuit to the variations of any parameter depends on the value of all, including the variable, parameters of a bridge arm, i.e., within the measuring range the sensitivity is a variable. In this connection, when designing balanced ac bridges, it becomes necessary to find out for what relations of the bridge parameters it is possible to ensure a given sensitivity to the variations of the parameters being measured; to find the pattern of the bridge circuit sensitivity variations with respect to the unknown and, in the case of an automatic bridge, also with respect to the balancing parameter variations over the entire measuring range; and having obtained this pattern, to find out the numerical values of sensitivity at characteristic points (for instance, at the extremes of sensitivity, etc.)

In order to solve these problems by the analytical method, a large calculating operation is required; it is more convenient to analyze ac bridge circuits by means of topographic diagrams, whose application has been developed to a considerable extent by various authors [1-4].

In [1 and 2] the topographical diagrams, included the plotting and study of trajectories of the potentials across the bridge-measuring diagonals, when the bridge parameters were varied (the so-called balancing lines), thus providing a complete picture of the balancing process, which was not limited to small deviations from balance. Next it was shown in [3] that for various four-arm bridges only several types of definite balancing lines were possible, and on this basis the conception of generalized bridge parameters was introduced, each parameter being related to a definite type of balancing lines. Owing to the introduction of the generalized parameter, it became possible to plot a single universal family of balancing curves, which corresponded to variations of the generalized parameters, applicable for the analysis of the convergence of a wide range of bridge circuits. In [4] it was proposed to superimpose on this diagram lines of equal sensitivity. Such a diagram provides a graphical picture of the sensitivity variations over the whole measuring range. In [4] equal sensitivity lines were plotted both for bridge circuits with null indicators and separate balancing differential indicators. These diagrams, however, were designed for analyzing the sensitivity when two similar parameters of the bridge arm were changed (for instance, two resistances).

This article deals with the plotting of equal sensitivity lines of bridge circuits with null phase-sensitive indicators (NPSI) which are widely used both in manual and automatic balancing of bridge circuits [5].

The diagrams thus obtained also provide an analysis of the sensitivity of bridge circuits with amplitude null indicators.

Circuit No.	Type of circuit	Phase angle sign	α	β	γ
1		—	R_1	R_2	ωL
2		+	R_1	R_2	$\frac{1}{\omega C}$
3		—	$\frac{1}{\omega C_1}$	$\frac{1}{\omega C_2}$	R
4		—	$\frac{1}{R_2}$	$\frac{1}{R_1}$	ωC
5		+	ωC_2	ωC_1	$\frac{1}{R}$

The Choice of Generalized Parameters. We shall only examine four-arm bridges with two three-element arms of five different types (see table). Circuits with positive phase angles (between voltage $\dot{U}$ across the left-hand side of the circuit and that of the supply U_n) are designated in the table with a plus sign and those with a negative angle designated with a minus sign. A bridge circuit which can be balanced is formed from two circuits with similar single phase angles. When the end terminals of a circuit (a and b) are interchanged, the phase angle sign is reversed. From the five circuits under consideration, 14 independent four-arm bridge circuits can be formed. On the assumption that the input impedance of the ac bridge indicating devices is sufficiently high, we shall henceforth consider independently the various arms of the bridge circuits. Thus, the analysis of the sensitivity of bridge circuits of the above types is reduced to the analysis of the sensitivity of five three-element circuits.

In order to be able to analyze simultaneously the properties of the five circuits, it is necessary to use the concept of generalized parameters of a three-element circuit. The essence and the possibility of analyzing bridge circuits by means of generalized parameters will become clearer, if the concept of generalized parameters is approached directly by examining the expression for the voltage between the left-hand side and middle terminals of the circuit, instead of comparing the balancing lines plotted for various circuits, as it was done in [3, 4]:

$$\dot{U}=\frac{\dot{Z}_1}{\dot{Z}_1+\dot{Z}_2}U_n. \tag{1}$$

Any of the physical parameters (R, L, or C), depending on the structure of the circuit, can form part of $\dot{Z}_1$ or $\dot{Z}_2$, moreover, the relation of $\dot{Z}_1$ and $\dot{Z}_2$ to any of the parameters can be different. Therefore $\dot{U}$ will change according to different laws when in different circuits the value of the same parameter is changed according to a given law.

Let us first examine circuits 1-3.

If the resistances and reactances of circuits 1-3 are denoted by α, β, and γ, Eq. (1) assumes the form:

$$\dot{U}=\frac{\alpha}{\alpha\pm\beta\pm j\gamma}U_n \tag{2}$$

Each of the quantities α, β, and γ occupies a definite place in (2), and hence the variation of any one of these quantities with the others remaining constant will produce a definite law of variation in $\dot{U}$. Thus, if α, β, and γ are assumed to be generalized parameters, the variation of each generalized parameter $\dot{U}$ will correspond to a definite type of vector trajectory in the balancing plane (on the topographical diagram), moreover, it is understood that only three types of trajectories are possible. Since $\dot{U}$ is a linear fraction function, these trajectories will be circles whose characteristic points can be determined directly from the examination of (2).

From (1) and (2) we can determine the generalized parameters: α is the impedance connected in the non-complex arm; β is the component of the complex arm of the same type as α; γ is the component of the complex arm of a different type than α. For the evaluation of 4 and 5 it is more convenient to express $\dot{U}$ by means of admittances:

$$\dot{U}=\frac{\dot{Y}_2}{\dot{Y}_1+\dot{Y}_2}U_n. \tag{3}$$

If the circuits 4 and 5 are arranged in the manner shown in the table, i.e., so that $\dot{Y}_2$ is not complex, then (3) can be represented in the same form as (2) and hence the above determination will hold, with the exception that instead of impedances, real and imaginary parts of admittances are being used in circuits 4 and 5.

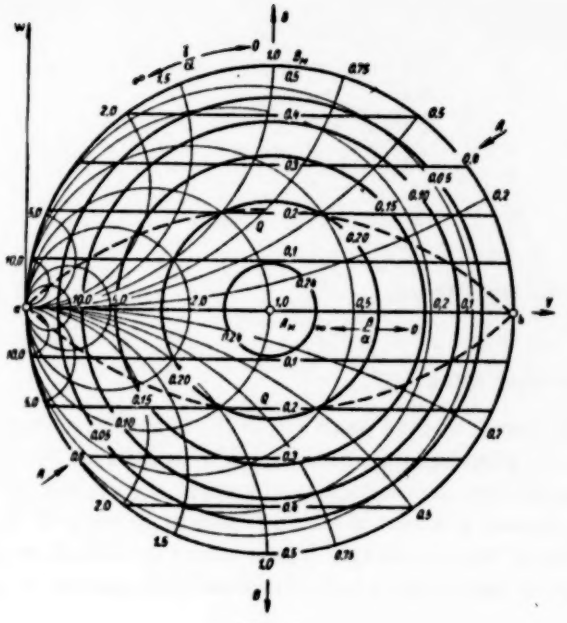


Fig. 1

The basic advantage of the generalized parameters α, β, and γ is that each one of them is only related to one of the actual variable parameters (R, L, or C).

If, however, all the three parameters, α, β, and γ be considered as independent variables, it will be impossible to represent completely function $\dot{U}$ (or its derivative) by one common family of curves in the balancing plane; for this purpose several such families of curves would be required, each of which would hold for a certain fixed value of one of the parameters.

Function $\dot{U}$ can be determined by means of two parameters if the latter are represented as ratios of α, β, γ as shown in expression:

$$\dot{U}=\frac{1}{1+\frac{\beta}{\alpha}\pm j\frac{\gamma}{\alpha}}U_n=\frac{\frac{\alpha}{\beta}}{\frac{\alpha}{\beta}+1\pm j\frac{\gamma}{\beta}}U_n=\frac{\frac{\alpha}{\gamma}}{\frac{\alpha}{\gamma}+\frac{\beta}{\gamma}\pm j}U_n. \quad (4)$$

However, when for the purpose of plotting the diagram, one of the pairs of ratios is taken β/α and γ/α or α/γ and β/γ) it is necessary to remember that in fact the independent parameters are R, L, and C, which are equivalent to α, β, and γ and it can happen that by changing one of them both generalized parameters will change. In the latter case the plotted balancing and equal sensitivity curves will be useless, since they can only be valid if it is assumed that only one of the generalized parameters is changing. Therefore, if it is desired to analyze by means of the equal sensitivity curves, the bridge sensitivity with respect to variable parameters β and γ, it is not permissible to choose for generalized parameters γ/α and γ/β, since γ figures in both the generalized parameters.*

Thus the choice of the generalized parameters should be determined by the conditions of the problem which it is required to solve.

Considering that in designing ac bridges the effect of parameters γ and β on the sensitivity of the bridge are of greater interest, it is best to choose as generalized parameters $\beta/\alpha=\mu$ and $\gamma/\alpha=\rho$, which provide the possibility of plotting curves of equal sensitivity for variables γ and β and finding from them the sensitivity with respect to variations of α.

Curves of Equal Moduli of Sensitivity. In order to find whether it is possible to attain a certain sensitivity with respect to variations of the unknown parameters in a given bridge circuit, it is convenient to use the concept of the sensitivity of the bridge circuit with a null phase-sensitive indicator to a relative change in a parameter

$$S_q=\lim_{\Delta q\to 0}\frac{\Delta U_\partial}{k_\partial U_n}:\frac{\Delta q}{q}=\frac{\partial U_\partial}{\partial q}\cdot\frac{q}{k_\partial U_n}, \quad (5)$$

where k_∂ is the gain of the null phase-sensitive indicator; U_∂ is the voltage at the output of the indicator; q is the parameter which determines the sensitivity.

The voltage at the output of the indicator working in the switching condition is

$$U_\partial=k_\partial Re\,[\dot{U}e^{-j\varphi}], \quad (6)$$

where φ is the angle of the phase difference between the reference and the bridge supply voltages.

* These ratios were taken in [4] as the generalized parameters.

Substituting (6) in (5) we obtain:

$$S_q = Re\left[\frac{\partial \dot{U}}{\partial q} \cdot \frac{q}{U_n} \cdot e^{-j\varphi}\right]. \tag{7}$$

But $\frac{\partial \dot{U}}{\partial q} \cdot \frac{q}{U_n} = \dot{S}_q$ the complex specific sensitivity.

Thus,

$$S_q = Re[\dot{S}_q e^{-j\varphi}] = |\dot{S}_q| \cos(\Theta_q - \varphi), \tag{8}$$

where $|\dot{S}_q|$ is the modulus and Θ_q the argument of the complex sensitivity.

Sensitivity S_q depends both on the parameters of the circuit and the phase (φ) of the reference voltage. By changing φ it is possible to vary the sensitivity from zero to its maximum, equal to $|\dot{S}_q|$. In order to find out whether a given bridge circuit can provide the required sensitivity, it is sufficient to analyze the expression for the modulus of the complex sensitivity. With this object in view it is best to plot a family of curves with equal moduli in the balance plane which already carries a family of balance curves. These curves determine at each point of the balance plane the maximum sensitivity for given parameters which it is possible to provide by an appropriate choice of the reference voltage phase.

Let us now plot in the balance plane (in the complex plane of vector $\dot{U}/U_n$) curves

$$|\dot{S}_\mu| = A = \text{const} \;\&\; |\dot{S}_\rho| = B = \text{const},$$

where

$$\mu = \frac{\beta}{\alpha}, \quad \rho = \frac{\gamma}{\alpha}.$$

(Henceforth we shall remember that $\dot{S}_\mu = \dot{S}_\beta$ and $\dot{S}_\rho = \dot{S}_\gamma$.)

For this purpose it is necessary to find the relations between the components of $\dot{U}/U_n$ (the abscissa V and the ordinate W in the plane $\dot{U}/U_n$) and the quantities $|\dot{S}_\mu|$ and $|\dot{S}_\rho|$.

Considering that

$$\dot{U} = \frac{1}{\mu + 1 \pm j\rho} U_n, \tag{4 a}$$

let us express $|\dot{S}_\mu|$ and $|\dot{S}_\rho|$ by means of the generalized parameters μ and ρ

$$|\dot{S}_\mu| = \left|\frac{\partial \dot{U}}{\partial \mu} \cdot \frac{\mu}{U_n}\right| = \frac{\mu}{(\mu+1)^2+\rho^2}; \tag{9}$$

$$|\dot{S}_\rho| = \left|\frac{\partial \dot{U}}{\partial \rho} \cdot \frac{\rho}{U_n}\right| = \frac{\rho}{(\mu+1)^2+\rho^2}. \tag{10}$$

We have from (4 a):

$$\frac{\dot{U}}{U_n} = \frac{\mu + 1 \mp j\rho}{(\mu+1)^2+\rho^2} = V + jW. \tag{11}$$

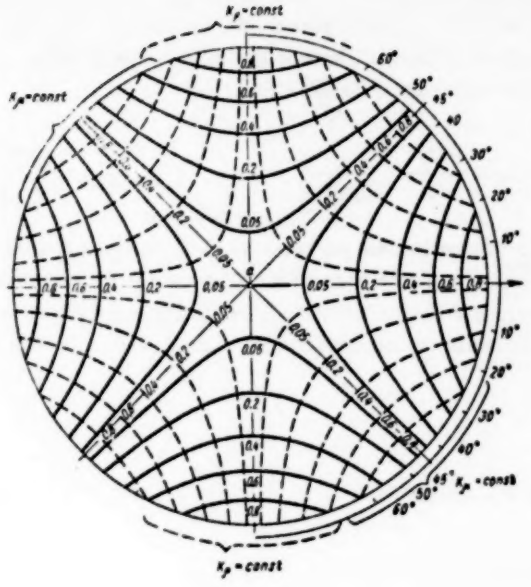


Fig. 2

Whence

$$V=\frac{\mu+1}{(\mu+1)^2+\rho^2}; \tag{12}$$

$$W=\mp\frac{\rho}{(\mu+1)^2+\rho^2}. \tag{13}$$

Comparing (10) and (13) we obtain the equation of curves for equal moduli of specific sensitivity with respect to the unknown parameter ρ; curves which are straight lines parallel to the X-axis:

$$W=\mp|\dot{S}_\rho|=\pm B. \tag{14}$$

Considering that

$$V^2+W^2=\frac{1}{(\mu+1)^2+\rho^2},$$

we find the equation of the curves for equal moduli of specific sensitivity with respect to parameter μ:

$$V^2+W^2-V+A=0. \tag{15}$$

This is an equation of circumference of radius $r=\frac{\sqrt{1-4A}}{2}$ with its center in point $V=\frac{1}{2}$; W = 0.

The family of curves of equal moduli of specific sensitivity in the plane $\dot{U}/U_n$ is shown in Fig. 1. The same diagram shows a family of balancing curves μ = var; ρ = const; and μ = const; ρ = var, similar to the one plotted in [3]. The point of interest to us in the balancing plane, determined by the parameters μ and ρ, is located at the point of intersection of the balance curves with the corresponding indexes.

Figure 1 shows that the regions of greatest sensitivity with respect to variations of parameters μ and ρ are situated in different parts of the balancing plane. The region of the greatest sensitivity with respect to μ is situated near point A_M, and the region of the greatest sensitivity with respect to ρ, near point B_M. The locus of points where $|\dot{S}_\mu| = |\dot{S}_\rho|$ is a circle with its center in point $V_0 = -1/2$; $W_0 = \pm 1/2$ with a radius of $\sqrt{2}/2$. Point Q which lies on that circumference and has the largest ordinate is the point of the maximum possible sensitivity for both parameters. At that point

$$|\dot{S}_\rho|=|\dot{S}_\mu|=0.207.$$

Hence when it is required to obtain the maximum sensitivity for variations of μ, the circuit parameters should be chosen so as to place the operation range near point A_M; for the maximum sensitivity of variations of ρ the operating range should be placed near point B_M, and for the maximum sensitivity of simultaneous variations of μ and ρ the operating range should be placed near point Q.

The modulus of the specific complex sensitivity $|\dot{S}_q|$ is numerically equal to the specific sensitivity of the bridge circuit with a normal amplitude null indicator, since the latter reacts precisely to the modulus of the voltage at the measuring diagonal. So, the diagram of Fig. 1 can also be used for determining the sensitivity of bridge circuits with null amplitude indicators.

If we understand similarly to [1] and [4], the region of maximum balance to be the one inside which the sensitivity with respect to variations of both parameters does not fall below a given value, it becomes clear from the above that such a region would consist of a sector in the central part of the balancing plane bounded by a straight line and a circumference with given indexes, when amplitude null indicators are used.

Equal Sensitivity Curves of a Bridge Circuit When Null Phase-Sensitive Indicators (NPSI) are Taken Into Account. When check calculations of bridges with NPSI are made, after a preliminary choice of bridge parameters, with the object of finding the variations of sensitivity over the whole measuring range, taking into account the reference voltage phase, and determining the sensitivity at characteristic points, the sensitivity with respect to the relative variation of parameter S_q [see (5)] is no longer of interest, whereas the relative sensitivity with respect to the absolute variation of parameter K_q becomes the relevant consideration:

$$K_q = \lim_{\Delta q \to 0} \frac{\Delta U_\partial}{k_\partial U_n} : \Delta q = \frac{\partial U_\partial}{\partial q} \cdot \frac{1}{k_\partial U_n}. \tag{16}$$

Even in the case when it is convenient to operate with dimensionless parameters in investigating the dynamic properties of bridges, the parameter increments (Δq) are referred to some parameter q_c constant for the whole measuring range (for instance, to the mean or the maximum), and not to quantity q which has a different value for each point of the balancing plane. Hence, in this case it is also more convenient to deal with quantity K_q instead of S_q.

Let us now plot on the balancing plane curves

$$K_\mu = \text{const} \;\&\; K_\rho = \text{const}.$$

For this purpose let us express K_μ and K_ρ in terms of μ and ρ:

$$K_\mu = Re\left[\frac{\partial \dot{U}}{\partial \mu} \cdot \frac{1}{U_n} e^{-j\varphi}\right] = \frac{-[(\mu+1)^2-\rho^2]\cos\varphi \pm 2(\mu+1)\rho\sin\varphi}{[(\mu+1)^2+\rho^2]^2}, \tag{17}$$

$$K_\rho = Re\left[\frac{\partial U}{\partial \rho} \cdot \frac{1}{U_n} e^{-j\varphi}\right] = \frac{\mp 2(\mu+1)\rho\cos\varphi - [(\mu+1)^2-\rho^2]\sin\varphi}{[(\mu+1)^2+\rho^2]^2}. \tag{18}$$

In conjunction with (12) and (13) let us now express K_μ and K_ρ on the basis of (17) and (18) in terms of V and W:

$$K_\mu = -(V^2-W^2)\cos\varphi - 2VW\sin\varphi; \tag{19}$$

$$K_\rho V = 2W\cos\varphi - (V^2-W^2)\sin\varphi. \tag{20}$$

Let us first assume that $\varphi = 0$.

Then the equal sensitivity curves will take the form:

$$K_\mu = W^2 - V^2; \tag{21}$$

$$K_\rho = 2VW. \tag{22}$$

Equations (21) for K_μ = const and (22) for K_ρ = const are those of equilateral hyperbolas in the balancing plane. The family of equal sensitivity curves is shown in Fig. 2.

Now it is possible to determine the position of the equal sensitivity curves in the balancing plane for $\varphi \neq 0$. It is easy to show that (19) is an equation of a hyperbola similar to the one described by (21), but rotated with respect to the origin of the coordinates through angle $\varphi/2$, and (20) represents a hyperbola similar to the one of (22) but also turned through an angle of $\varphi/2$. In order to express Eqs. (19) and (20) in new coordinates V' and W' turned with respect to the old ones through angle $\varphi/2$ it is sufficient to express in (19) and (20) the values of the old coordinates in terms of the new coordinates.

$$V = V'\cos\frac{\varphi}{2} - W'\sin\frac{\varphi}{2};$$

$$W = V'\sin\frac{\varphi}{2} + W'\cos\frac{\varphi}{2}.$$

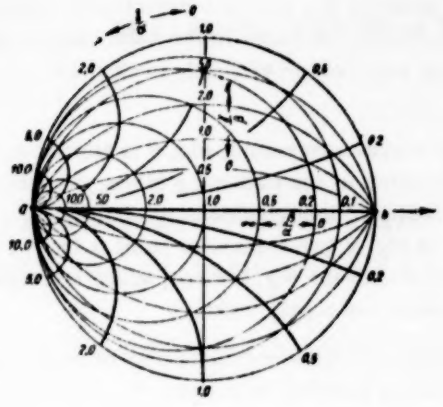


Fig. 3

Thus, in order to account for the phase difference between the reference voltage with respect to the supply voltage (φ) it is sufficient to turn the family of curves shown in Fig. 2 about the origin of the coordinates through an angle of $\varphi/2$.

Let us now show how it is possible by using the family of curves plotted in Fig. 2 to calculate the sensitivity with respect to parameter α. For this purpose let us use the general property of the measuring circuits with the differences between the dependent variables reduced to zero; this property consists of the sensitivities to the variation of definite parameters related to each other as the derivatives of the conditions of balance of these parameters [6]. In other words the condition of the bridge balance is

$$H=\dot{Z}_2\dot{Z}_4-\dot{Z}_1\dot{Z}_3=0, \tag{23}$$

then

$$\frac{\frac{\partial \dot{U}}{\partial \alpha}}{\frac{\partial \dot{U}}{\partial \beta}}=\frac{\frac{\partial \dot{H}}{\partial \alpha}}{\frac{\partial \dot{H}}{\partial \beta}}, \tag{24}$$

whence

$$\frac{\partial U}{\partial \alpha}=\frac{\partial \dot{U}}{\partial \beta}\cdot\frac{\frac{\partial \dot{H}}{\partial \alpha}}{\frac{\partial \dot{H}}{\partial \beta}}=-\frac{\dot{Z}_2}{\dot{Z}_1}\cdot\frac{\partial \dot{U}}{\partial \beta}$$

or

$$\frac{\partial \dot{U}}{\partial \alpha}=-\frac{\mu\pm j\rho}{\alpha}\cdot\frac{\partial \dot{U}}{\partial \mu}. \tag{25}$$

The specific sensitivity to variations of a parameter is determined by the formula

$$K_\alpha=Re\left[\frac{\partial \dot{U}}{\partial \alpha}\cdot\frac{1}{U_n}\,e^{-j\varphi}\right]. \tag{26}$$

Let us represent $\frac{\mu\pm j\rho}{\alpha}$ in an exponential form:

$$\frac{\mu+j\rho}{\alpha}=\frac{m}{\alpha}\,e^{j\psi}, \tag{27}$$

where $m=\sqrt{\mu^2+\rho^2}$; $\psi=\operatorname{arctg}\frac{\pm\rho}{\mu}$.

By substituting (25) in (26) and expressing $\partial\dot{U}/\partial\mu$ in terms of V and W we obtain:

$$K_\alpha=-\frac{m}{\alpha}[(V^2-W^2)\cos(\varphi-\psi)-2VW\sin(\varphi-\psi)]. \tag{28}$$

From the comparison of (28), (19) and (20) it becomes clear how quantity K_α can be determined by means of the family of curves K_μ = const (Fig. 2), since for this purpose it is sufficient to rotate in the balancing plane about the origin of the coordinates the whole family of curves through an angle of $\varphi - \psi/2$ and, having read off the value K_μ at the appropriate point, multiply that value by $-m/\alpha$.

In order to make practical use of the family of equal sensitivity curves convenient, Fig. 2 is plotted on tracing cloth. In order to determine the required sensitivities at various points of the balancing plane, the tracing cloth with the family of equal sensitivity curves is placed over the universal topographic diagram (Fig. 3), which is plotted to the appropriate scale in such a manner that point α in Fig. 2 coincides with point α in Fig. 3 and the arrow, which is the continuation of the ab axis in Fig. 3, coincides with the Fig. 2 mark, which corresponds to half the value of the phase difference angle between the bridge reference and supply voltages.

By comparing the indexes on the family of balancing curves diagram with those on the family of equal sensitivity curves diagram at the same points of the balancing plane, it becomes possible to analyze the variation of sensitivity inside the working range for a given angle φ and a given measuring range, and to determine rapidly the values of sensitivity for characteristic points, or to determine for a given range of sensitivity variations the possible relations between bridge arm parameters. When the designer has a free choice of angle φ, it is possible to select an optimum value of angle φ by rotating the family of equal sensitivity curves about the origin of the coordinates in Fig. 3 and analyzing the distribution of sensitivity in the working range.

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* See English translation.

MEASUREMENTS OF CURRENT BY MEANS OF THERMISTOR BRIDGES AT FREQUENCIES UP TO 1000 Mc.

G. M. Strizhkov and B. E. Rabinovich

Thermistors can be used for measuring current at UHF since their resistance varies with the power consumed. For this purpose, however, it is necessary to know, in addition to the power consumed, also the resistance $R_{T\omega}$ of the thermistor at UHF, which, in general, differs from its resistance R_{T0} at dc. Such a thermistor current meter in conjunction with a small nonreactive resistor can be used as a source of small voltages at frequencies up to 1000 Mc.

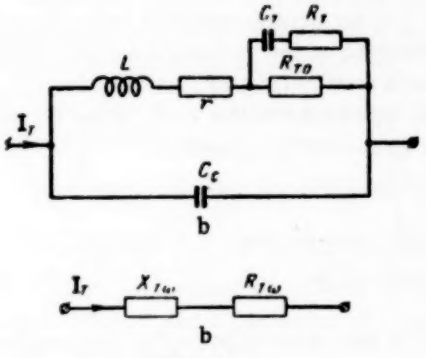

Fig. 1

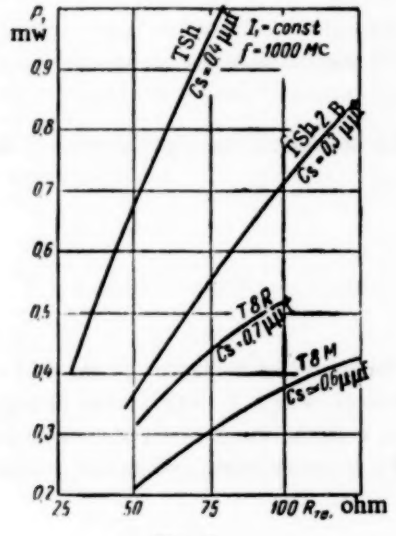

Fig. 2

It is expedient to begin the investigation of the thermistor as a current measuring device by examining its equivalent circuit.

A full equivalent circuit of a thermistor [1] is shown in Fig. 1a, which includes: C_C and C_T capacitances formed, respectively, by the connecting leads of the thermistor and between the particles of the semiconductor; L and r, the inductance and resistance of the connecting leads; and R_T, the resistance related to the power consumed by the thermistor.

In order to determine the error in current measurements, let us transform the equivalent circuit of Fig. 1a into a series circuit (Fig. 1b), neglecting the resistance of the connecting wires ($r \ll R_{T0}$) and taking C'_T to be a capacitance which includes R_T. Since the current is determined from the power consumed by the thermistor, we shall henceforth only consider the resistive component of the series circuit impedance. The validity of the adopted equivalent circuit is confirmed by the good agreement between the experimentally determined error $\Delta_0 I$ for thermistor TSh-2 and its square-law relationship to frequency (see Fig. 5).

Taking into consideration that $L \simeq 10^{-8}$ h; $C_C \simeq 0.03$ μμf * and $C'_T = (0.3\text{-}0.7)$ μμf, we obtain after tedious but obvious transformations:

$$R_{T\omega} \simeq \frac{R_{T0}}{1+\omega^2 R_{T0}\left[C_C^2 + (C'_T)^2 - 2\frac{L'C_C}{R_{T0}^2}\right]}. \qquad (1)$$

The value in square brackets is equivalent to a certain capacitance (C_s) which shunts the thermistor, i.e.,

$$C_s = \sqrt{C_C^2 + (C'_T)^2 - 2\frac{L'C_C}{R_{T0}^2}}. \qquad (2)$$

* According to A. M. Felorov's data.

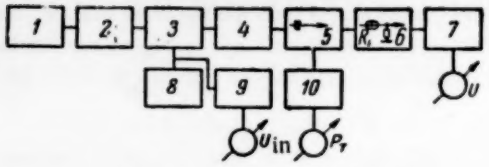

Fig. 3. 1) Oscillator GSS-12; 2) RF filter; 3) UHF switch; 4) 10 db attenuator AS-1; 5) separating device; 6) measuring head; 7) measuring instrument IP-2; 8) absorbing load UEA-5; 9) v. t. voltmeter VKS-7B; 10) thermistor bridge.

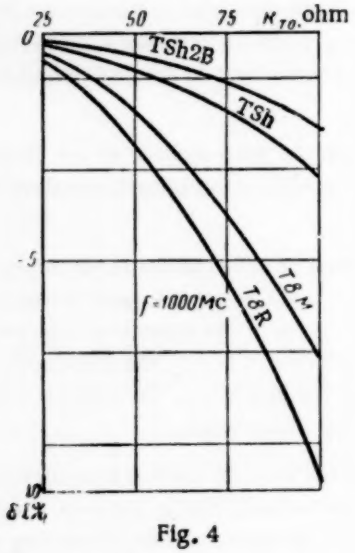

Fig. 4

where

$$L'=L\left\{1-\frac{C_T' R_{T0}^2}{L\left[1+\omega^2\left(C_T'\right)^2 R_{T0}^2\right]}\right\}\simeq L\left(1-\frac{C_T' R_{T0}^2}{L}\right). \quad (3)$$

By substituting the value of L' we obtain

$$C_s^2 \simeq \left(C_C + C_T'\right)^2 - 2\,\frac{LC_C}{R_{T0}^2}. \quad (4)$$

The actual value of the current flowing through the thermistor can be found from the formula

$$I_T = \sqrt{\frac{\overline{P_T}}{R_{T\omega}}} \simeq \simeq \sqrt{\frac{\overline{P_T}}{R_{T0}}\left(1+\frac{1}{2}\omega^2 R_{T0}^2 C_s^2\right)}. \quad (5)$$

Hence it follows that the determination of the current from the power P_T consumed by the thermistor and its resistance R_{T0} at dc involves a systematic error, which is related to frequency and the type of thermistor used. From (5) we find the relative error in current measurements

$$\delta I = \frac{1}{\sqrt{1+\omega^2 R_{T0} C_s^2}} - 1 \simeq -\frac{1}{2}\omega^2 R_{T0}^2 C_s^2. \quad (6)$$

Formula (6) is approximate, but sufficiently accurate for practical use, since its error is one order lower than δ I.

It follows from (5) that δI is proportional to R_{T0}^2; hence it is advisable to measure the current at the lowest possible values of R_{T0}, the remaining factors being equal.

Thus, in order to be able to calculate the systematic error of current measurement by means of a thermistor, it is necessary to determine capacitance C_s.

Let us assume that at dc the value of C_s is independent of R_{T0} of the thermistor, i.e., let us consider that

$$2\,\frac{C_C L}{R_{T0}^2} \ll \left(C_C + C_T'\right)^2.$$

The justification for this assumption will be given later.

Having made this assumption let us find the relative increment of the power δP measured by the thermistor bridge for two values of R_{T0} at a given frequency ω, but at a constant value of current I_T which flows through the thermistor (see Fig. 1). For this purpose it is advisable to connect in series with the thermistor a low value resistor ($R_1 \simeq 10^{-2}$ ohm) and to regulate the current by means of the indication of a receiver connected to this resistance. Then:

$$\delta P = \frac{R_T^{\cdot} - R_T'}{R_T'} = \frac{R_{T0}^{\cdot}}{R_{T0}'} \cdot \frac{1+\omega^2 C_s^2 \left(R_{T0}\right)^2}{1+\omega^2 C_s^2 \left(R_{T0}'\right)^2} - 1. \quad (7)$$

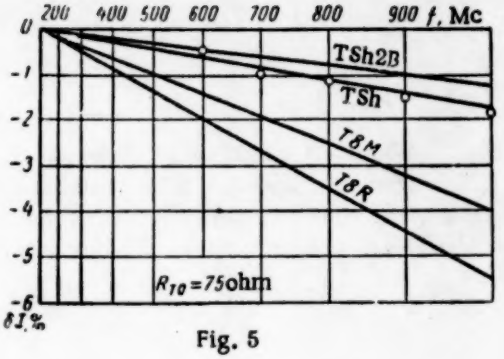

Fig. 5

Solving (7) with respect to C_s we find:

$$C_s = \frac{1}{\omega}\sqrt{\frac{\kappa - 1 + \delta P}{(R''_{T0})^2(1+\delta P)^2 - \kappa(R'_{T0})^2}}, \qquad (8)$$

where $k = R''_{T0}/R'_{T0}$.

Figure 2 shows the relation $P_T = f(R_{T0})$ taken for various types of thermistors at 1000 Mc and a constant I_T. The same graph shows values of C_s calculated from (8) and the relation $P_T = f(R_{T0})$.

The block schematic of the experiment for determining C_s is shown in Fig. 3.

The voltage of frequency ω is supplied through a radio frequency filter, 2, UHF switch, 3, attenuator, 4 (10 db), and separating device, 5, to measuring head, 6.

The measuring head consists of a segment of coaxial cable loaded at one end with a low value resistance R_1. The thermistor whose capacitance it is required to measure is connected to the central conductor in series with R_1.

Power P_T dissipated in the thermistor is measured with a reference bridge, 5, by substituting for power P_T a dc power. The tuning of the radio frequency filter is made by means of the indications of the v.t. voltmeter connected to the absorbing load UEA-5.

The stability of current I_T, which flows through the thermistor, is checked by means of the indications of the receiver connected to resistor R_1.

In order to justify the assumption made previously, power P_T was measured at small values of R_{T0} when the effect of term $2\frac{LC_C}{R^2_{T0}}$ is greatest. However, values of C_s calculated for R_{T0} = 20 to 30 ohm and for R_{T0} = = 80 to 100 ohm differed very little, therefore capacitance C_C can be considered one order lower than C'_T. Direct measurements of this capacitance at a low frequency placed its value at 0.02-0.03 $\mu\mu$f, thus the error of formula (8) does not exceed ± 10%.

Let us note that all the thermistors measured, types TSh-2 and TSh-2B have the lowest capacity C_s. Therefore, these types of thermistors should be used for UHF current measurements. Moreover, the thermistor resistance to dc should be kept as low as possible. Figures 4 and 5 show relative errors of δI for various types of thermistors. The range of the measured quantities depends in the main on the type of thermistors. In practice it has been found that it is possible to measure currents from 1 to 10 ma by means of thermistors of the above types.

In conclusion it should be noted that capacitance C_s can be measured by means of varying R_{T0} at frequencies above 1000 Mc.

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A CASCADE REFLEX VOLTMETER

Yu. V. Mikhatskii

The reflex voltmeter circuit (Fig. 1) is now being widely used. This circuit is being used for measuring the dc voltage of sources with a very high output resistance. Owing to its large negative feedback this circuit has a number of valuable features [1]: a) a large input and a small output resistance; b) the possibility of measuring voltage over a wide range; c) a linear scale; d) a very stable gain which provides a constant calibration with changing supply voltages and different tubes.

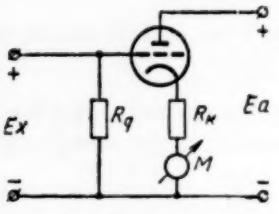

Fig. 1

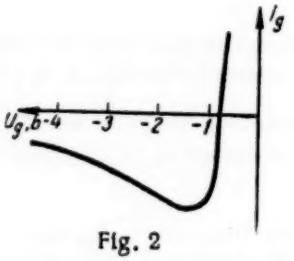

Fig. 2

However, the input resistance of the reflex voltmeter does not normally exceed $10^8 - 10^9$ ohm. Where it is necessary to have higher input resistances, electrometer tubes are used. However, electrometer tubes with an input resistance of 10^{13}–10^{14} ohm lack some of the advantages of the reflex circuit.

In the first place they lack a wide range; it is only possible to measure by means of electrometer tubes voltages up to 2-3 v. The use of potential dividers with a resistance of $10^{13} - 10^{14}$ ohm is in practice impossible owing to the instability of the voltage ratio thus obtained.

We describe below a circuit of a cascade reflex voltmeter which possesses all the advantages of a normal reflex voltmeter and has an input resistance of the order of $10^{11} - 10^{12}$ ohm.

The input resistance of a reflex circuit is determined by the grid currents of the tube. The basic components of the grid current of receiving voltage amplifier tubes are the electronic and ionic components, the thermoelectric circuit current, and conductance currents [2]. The remaining components are of a secondary character. The shape of the curve of the total grid current is shown in Fig. 2.

The peculiarity of a reflex circuit is its operation with large negative biases; in such a case the grid current is negative. This means that main components in a reflex voltmeter tube grid current consist of the ionic current and the thermoelectric circuit current. The latter can be greatly reduced by using a lower heater voltage.

The value of the ionic current for any given tube depends on the anode current and anode voltage; the ionic current decreases with their reduction. When the anode voltage is reduced, the grid current falls rapidly; at 6-9 volts the ionization stops. This condition is characteristic for electrometer tubes.

The grid current of the first tube in the reflex cascade voltmeter (Fig. 3) is considerably reduced owing to a small anode current. This is attained by connecting a very large resistance R_{k1} of the order of tens and hundreds of meg in the cathode circuit of the tube. Tests showed that in a tube of the 6S1Zh type with $R_{k1} = 45$ meg and a reduction of the heater voltage to 4 v, the grid current dropped to a value of 10^{-12} amp.

Resistor R_{k1} serves as a grid resistance for the second stage and should satisfy the grid current requirements of that stage. Resistor R_{k2} should have a low value sufficient for connecting a measuring instrument in the cathode of that tube.

On the basis of a cascade reflex voltmeter a pulse voltmeter model was developed and constructed for measuring voltages of single and repeated pulses with a large duty ratio. The voltmeter circuit is shown in Fig. 4.

The input of the circuit consists of a cathode follower which provides the possibility of measuring pulse voltages from a relatively high impedance source. From the output of the cathode follower the pulses are fed to a

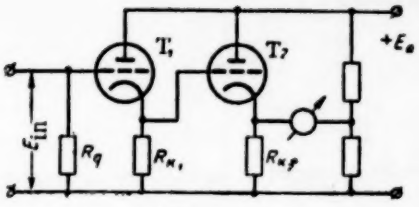

Fig. 3

diode detector connected in a parallel circuit. The dc voltage formed at the detector capacitor is measured by the cascade reflex voltmeter. The first stage of the reflex voltmeter uses tube 6S1Zh since its leakage resistance can be made sufficiently large. Hence the discharge time constant is sufficiently large even with a small capacitance. The latter circumstance provides measurement of pulses of a relatively small duration.

The voltmeter has two ranges: 50 and 250 v. The changeover from one range to the other is accomplished by means of a range switch (in Fig. 4 it is shown in the 250 v position), which changes the anode supply voltage and switches over the resistors of the bridge circuit in the cathode of tube T_4. Switch S_2 (in Fig. 4 shown in the position of "single pulses") serves to preserve the same voltmeter calibration for measuring single and repeated pulses: the variation of the resistance connected in series with the milliammeter compensates for the difference in the dc voltage formed by the charging capacitor in the grid circuit of tube T_3. Push button S_1 serves to quickly discharge this capacitor (in Fig. 4 it is shown normally disconnected). The instrument is supplied from a stabilized source.

The tests of the voltmeter showed that:

1) Its scale is almost linear.

2) After preliminary warming up no drifting was observed (the instrument was under observation for 4 hours).

3) Video pulses of a duration of 3-5 μsec can be measured by means of the voltmeter;

4) The effective input resistance determined by the leakage resistance, and the grid current of the first tube is $2 \cdot 10^{11}$ ohm (the discharge time constant is equal to 400 sec).

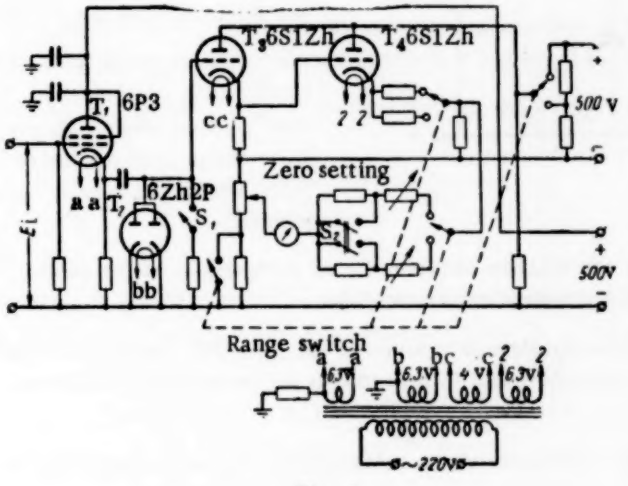

Fig. 4

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A REACTIVE METHOD OF MEASURING DIELECTRIC LOSSES

K. S. Polulyakh

The resonance method of measuring dielectric losses in radiotechnical materials at high frequencies is at present widespread.

Normally measurements are made with a very small coupling between measuring circuit and generator, and the calculations are made on the assumption that there is no reaction between the measuring and the oscillator circuits. The KV-1 Q-meter and instruments of the type of IP-3 and others are based on this principle [1].

With a weak coupling between the oscillator and the measuring circuit it is impossible to obtain high voltages across the measuring circuit, the circuit has to be tuned to resonance, and measurement results have to be obtained by calculation, thus involving loss of time. Yet in certain cases high measuring voltages are required, and for measuring the loss angle of large consignments of capacitors under shop conditions, instruments providing rapid measurements are required.

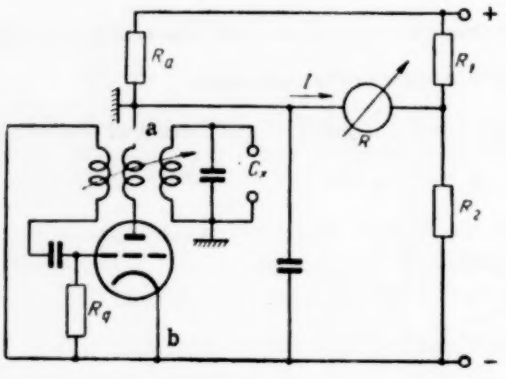

Fig. 1

For these purposes measurements with a close coupling between the oscillator and measuring circuits or a direct connection of the measured object into the oscillator circuit are widely used. In this case the strength of the measuring circuit reaction on the oscillator provides a measure of the parameter under test. This method provides the possibility of obtaining a direct reading instrument and a large voltage across the measuring circuit. We shall call this method henceforth the reactive method.

The reactive method is used in many instruments produced by our industry. These instruments are widely used in cases when high precision is not required. However, up to the present no theory of their operation exists and their working is usually described in a very simplified manner.

These instruments use the relation between the dc components of the anode current or the ac voltage across the oscillator circuit and its equivalent resistance [2].

In instruments for measuring dielectric losses of the type IPP, the relative variation of the equivalent resistance $\Delta R_e/R_e$ does not exceed 10% and in instruments for measuring scintillation of capacitors it amounts to less than 0.01%.

In this case the relative variation of the voltage $\Delta U_k/U_k$ can be expressed in terms of $\Delta R_e/R_e$ in the following manner:

$$\frac{\Delta U_k}{U_k} = k_p \frac{\Delta R_e}{R_e}, \qquad (1)$$

where k_p is a coefficient depending on the test conditions.

Having calculated or determined experimentally the load characteristics of the oscillator for a given R_e and various values of feedback and grid resistance R_g, it is possible to find a convenient operating range and sensitivity of the instrument being designed.

In actual instruments (for instance IPP, IMK-1 and ISK-1) the relation of the dc component of the anode current I_{a0} to $G_e = 1/R_e$ is used instead of the function $I_{a1} = \psi(G_e)$. In order to determine the design relations for these instruments, it is necessary to proceed from the relation of dc component I_{a0} and the first harmonic I_{a1} of the anode current expressed by the formula:

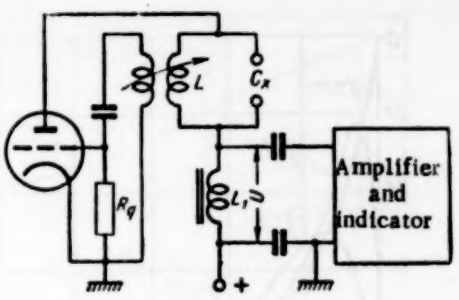

Fig. 2

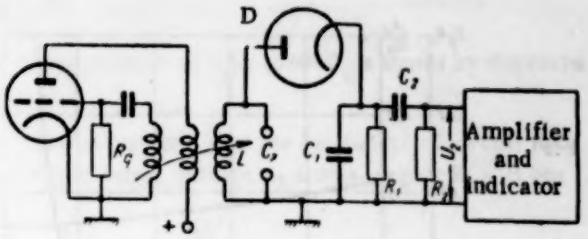

Fig. 3

$$\frac{\Delta I_{a1}}{I_{a1}} = \frac{\Delta I_{a0}}{I_{a0}} = k_p' \frac{\Delta G_e}{G_e}, \tag{2}$$

where k'_p is a coefficient depending on the conditions of testing and determined from the load characteristics of the oscillator.

Instruments IPP-1, IPP-2, and IPP-3 [3, 4, and 5] are direct reading instruments for measuring tanδ of capacitors. A simplified circuit of the instrument is shown in Fig. 1. The instrument is a dc bridge whose arms are formed by resistances R_a, R_1, R_2, and the dc resistance R_{ab} of the oscillator circuit between points a and b. Before testing the bridge is balanced. Next the capacitor under test is connected to terminals C_x. Thus the equivalent resistance R of the circuit and hence the dc component I_{a0} of the anode current are changed and the bridge unbalanced. The angle of the deflection of the measuring instrument connected across the bridge diagonal is a function of tanδ.

The instrument has a special device which makes its readings independent of C_x. By means of the same device the frequency of the oscillator is maintained constant for various values of C_x.

When the bridge is unbalanced, current I begins to flow through the bridge diagonal

$$I = \frac{E}{R + \dfrac{R_a R_i}{R_a + R_i} + \dfrac{R_1 R_2}{R_1 + R_2}}, \tag{3}$$

where R_i is the internal resistance of the tube; R is the resistance of the bridge diagonal; E is the open circuit voltage across the diagonal (for $R = \infty$, $E = \Delta I_{a0} R_a$). Then in conjunction with (2) we have

$$I = \frac{I_{a0} R_a k_p' \dfrac{\Delta G_e}{G_e}}{R + \dfrac{R_a R_i}{R_a + R_i} + \dfrac{R_1 R_2}{R_1 + R_2}}.$$

Instruments of the type ISK-1 and IMK-1 [3, 4, and 6] are designed to measure scintillation of capacitors.

It follows from [6] that scintillation consists of sudden random changes in the capacitance, and losses observable in certain types of capacitors. The simplified circuits of these instruments, shown in Fig. 2, are similar to the one of Fig. 1. It differs from the latter, however, by dispensing with the measurement of the static variations of current I_{a0}, and having a dynamic operating condition instead, because the changes of the equivalent oscillator circuit resistance R_e in this case are rapid and sudden. The anode resistor R_a of the former circuit (Fig. 1) is now replaced by coil L_1 with a ferromagnetic core (Fig. 2). Sudden variations of the dielectric losses of capacitor C_x produce changes in the dc component I_{a0} of the anode current. This produces across inductor L_1 a voltage pulse which is amplified and registered on the indicating instrument.

The speed of variations of the anode current for instantaneous changes of R_e is determined by the time constant of the oscillator circuit (L, C_x) if the grid circuit time constant is small. The rise of the dc component i_{a0}

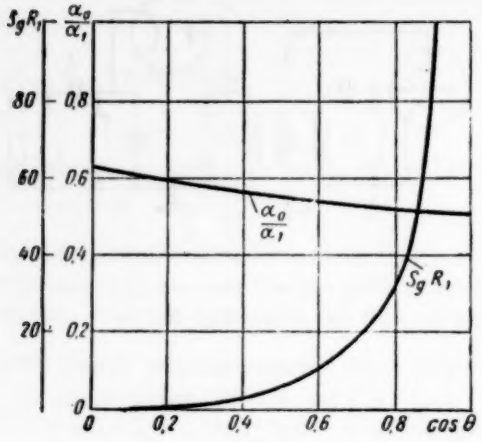

Fig. 4

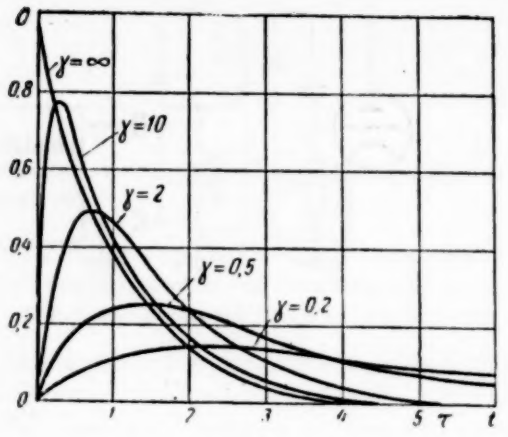

Fig. 5

of the anode current from I_{a0} to $I_{a0} + \Delta I_{a0}$ proceeds exponentially:

$$i_{a0} = I_{a0} + \Delta I_{a0}(1 - e^{-\frac{t}{\tau}}), \tag{4}$$

where $\tau = 2Q/\omega_0 = 2C_x R_e$ is the tuned circuit time constant, C_x is its capacity, Q is its quality factor and ω_0 is the oscillator angular frequency.

When current i_{a0} flows through inductor L_1, it produces voltage pulses u in the coil

$$u = -L_1 \frac{di_{a0}}{dt}.$$

Having determined di_{a0}/dt from (4) we obtain:

$$u = -\frac{L_1}{\tau} \Delta I_{a0} e^{-\frac{t}{\tau}}.$$

Substituting ΔI_{a0} from (2) we find:

$$u = -I_{a0} \frac{L_1}{\tau} k_p' \frac{\Delta G_e}{G_e} e^{-\frac{t}{\tau}}. \tag{5}$$

Instruments ISK-3 [6] and ISK-3M (modernized) serve to measure scintillation in capacitors. Their simplified circuit is shown in Fig. 3. When a scintillating capacitor is connected to the oscillator circuit, it produces a parametric amplitude modulation of the high frequency voltage U_k. The modulated voltage is detected by the diode D. The detected voltage is amplified and fed to the indicator.

The rise of the high frequency current is exponential and its speed is determined by the oscillator circuit time constant. Voltage u_1 at the detector load R_1 is equal, according to the linear detector theory, to

$$u_1 = [U_k + \Delta U_k(1 - e^{-\frac{t}{\tau}})]\cos\Theta_g.$$

The cutoff angle of detector Θ_g is obtained from the expression:

$$S_g R_1 = \frac{\pi}{\operatorname{tg}\Theta_g - \Theta_g},$$

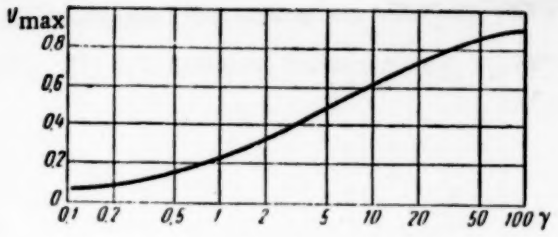

Fig. 6

where S_g is the slope of the diode detector characteristic.

The relation of $S_g R_1$ to $\cos\Theta_g$ is shown by the curve in Fig. 4.

If it is assumed that the bandwith of circuit R_2C_2 is infinitely large, voltage u_2 across resistor R_2 will be:

$$u_2 = -\Delta U_k \cos\Theta_g \, e^{-\frac{t}{\tau}}.$$

Substituting the value of ΔU_k from (1) we find:

$$u_2 = U_k k_p \frac{\Delta R_e}{R_e} \cos\Theta_g \, e^{-\frac{t}{\tau}}. \tag{6}$$

It follows from (5) and (6) that if there is any scintillation, we shall obtain an exponential pulse in the circuits of Figs. 2 and 3.

In conclusion let us examine the amplification of the exponential pulse and find a method of selecting the required amplifier bandwidth.

The bandwidth of the oscillator circuit (Figs. 2 and 3) is equal to

$$\Delta f_k = \frac{2}{\tau},$$

where τ is the circuit time constant.

The bandwidth of the low frequency amplifier is similarly expressed by means of the amplifier time constant τ_1:

$$\Delta f = \frac{1}{\tau_1} = \frac{1}{CR},$$

where R is the anode load resistance of the amplifier; C is the capacity shunting R.

Let us find the relation of the exponential pulse amplitude at the amplifier output to the expression

$$\gamma = \frac{2\Delta f}{\Delta f_k} = \frac{\tau}{\tau_1},$$

when an exponential pulse with a unit amplitude is fed to the amplifier input. The voltage envelope at the output of the low frequency amplifier is equal to the expression below([7])when voltage E(t) is fed to its input:

$$U(t) = \int_0^t A(T) E(t-T) \, dT. \tag{7}$$

A(t) can be determined from the knowledge of the voltage $U_1(t)$ at the amplifier output when a unit voltage impulse is fed to its input. By assuming in (7) that E = 1 we have:

$$U_1(t) = \int_0^t A(T) \, dT,$$

whence

$$A(t) = \frac{d}{dt} U_1(t) = \frac{1}{\tau_1} e^{-\frac{t}{\tau_1}}.$$

When at the output of the amplifier there appears an exponential pulse

$$E(t)=e^{-\frac{t}{\tau}}$$

we obtain

$$U(t)=\frac{1}{\tau_1}\int_0^t e^{-\frac{T}{\tau_1}} e^{-\frac{t-T}{\tau}} dT,$$

whence we have the voltage at the amplifier output

$$U(t)=\frac{\gamma}{\gamma-1}\left(e^{-\frac{t}{\tau}}-e^{-\frac{t}{\tau_1}}\right). \tag{8}$$

The shape of pulse U(t) at the output of the amplifier due to the feeding of an exponential pulse to its input is given in relation to quantity γ, which was found from the last expression, in the curves of Fig. 5.

Let us find the relation of the amplitude of pulse U_{max} at the output of the amplifier to ratio γ. By equating to zero the derivative dU/dt obtained from (8) we shall find an expression for the instant t_1 when U(t) attains its maximum value U_{max}:

$$t_1=\frac{\tau\ln\gamma}{\gamma-1}.$$

By substituting the values of t_1 from (8) we find the relation between the amplitude of pulse U_{max} and ratio γ:

$$U_{max}=\frac{\gamma}{\gamma-1}\left(e^{-\frac{\ln\gamma}{\gamma-1}}-e^{-\gamma\frac{\ln\gamma}{\gamma-1}}\right).$$

The function thus obtained was plotted in the form of a curve in Fig. 6. It will be seen from the graph that when the bandwidth of the amplifier is increased, the voltage at its output increases very slowly.

In our case only the amplitude of the pulse is of interest and not its shape, hence it is better to increase the gain of the amplifier rather than bandwidth since the latter is more difficult.

The curve of Fig. 6 provides the possibility of selecting a suitable bandwidth for the amplifier.

These relationships can serve as a basis for designing circuits shown in Figs. 1, 2, and 3, when constructing instruments of the type described above.

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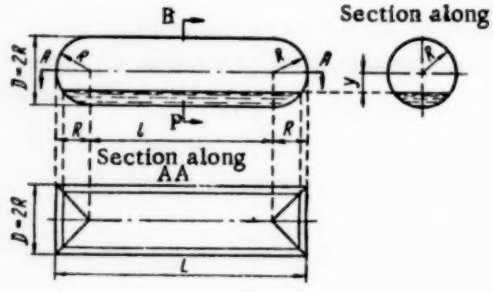
CALIBRATION IN CENTIMETER STEPS OF HORIZONTAL TANKS WITH CYLINDRICAL BOTTOMS

E. N. Lessig

Horizontal tanks with cylindrical bottoms, of 50, 75, and 100 m^3 capacity, whose design and calibration were worked out in [1, 2], are now coming into operation. At present, tanks of the same construction but of a capacity of 150 m^3 are being designed.



Measurements made by the All-Union Scientific Research Institute of Oil Construction of the Chief Gas Administration of the USSR and the Moscow Institute of Urban Civil Engineers of the Moscow City Soviet Executive Committee [3] showed that the horizontal tanks with cylindrical bottoms of 50, 75, and 100 m^3 capacity can operate at a pressure up to 0.7 kg/cm^2. From technical, economic, and operational considerations they have certain advantages as compared with tanks which have spherical, flat, or conical bottoms and they can also be used underground.

$\frac{H}{D}$	K_c	$\frac{H}{D}$	K_c	$\frac{H}{D}$	K_c	$\frac{H}{D}$	K_c	$\frac{H}{D}$	K_c	$\frac{H}{D}$	K_c	$\frac{H}{D}$	K_c	$\frac{H}{D}$	K_c
0.010	0.000	0.166	0.073	0.275	0.185	0.390	0.338	0.505	0.507	0.620	0.677	0.735	0.826	0.842	0.933
0.020	0.001	0.170	0.077	0.280	0.191	0.395	0.345	0.510	0.515	0.625	0.684	0.740	0.832	0.846	0.936
0.030	0.003	0.174	0.080	0.285	0.197	0.400	0.352	0.515	0.522	0.630	0.690	0.745	0.838	0.850	0.939
0.040	0.005	0.178	0.084	0.290	0.204	0.405	0.359	0.520	0.530	0.635	0.697	0.750	0.844	0.860	0.947
0.050	0.007	0.182	0.087	0.295	0.210	0.410	0.366	0.525	0.537	0.640	0.704	0.755	0.849	0.870	0.954
0.055	0.009	0.186	0.091	0.300	0.216	0.415	0.374	0.530	0.545	0.645	0.711	0.760	0.855	0.880	0.960
0.060	0.010	0.190	0.095	0.305	0.223	0.420	0.381	0.535	0.552	0.650	0.718	0.765	0.860	0.890	0.966
0.065	0.012	0.194	0.098	0.310	0.229	0.425	0.388	0.540	0.560	0.655	0.725	0.770	0.866	0.900	0.972
0.070	0.014	0.200	0.104	0.315	0.235	0.430	0.396	0.545	0.567	0.660	0.732	0.775	0.871	0.905	0.975
0.075	0.016	0.205	0.109	0.320	0.242	0.435	0.403	0.550	0.575	0.665	0.738	0.780	0.876	0.910	0.977
0.080	0.018	0.210	0.114	0.325	0.248	0.440	0.410	0.555	0.582	0.670	0.745	0.785	0.881	0.915	0.980
0.085	0.020	0.215	0.119	0.330	0.255	0.445	0.418	0.560	0.590	0.675	0.752	0.790	0.886	0.920	0.982
0.090	0.023	0.220	0.124	0.335	0.262	0.450	0.425	0.565	0.597	0.680	0.758	0.795	0.891	0.925	0.984
0.095	0.025	0.225	0.129	0.340	0.268	0.455	0.433	0.570	0.604	0.685	0.765	0.800	0.896	0.930	0.986
0.100	0.028	0.230	0.134	0.345	0.275	0.460	0.440	0.575	0.612	0.690	0.771	0.806	0.902	0.935	0.988
0.110	0.034	0.235	0.140	0.350	0.282	0.465	0.448	0.580	0.619	0.695	0.777	0.810	0.905	0.940	0.990
0.120	0.040	0.240	0.145	0.355	0.289	0.470	0.455	0.585	0.626	0.700	0.784	0.814	0.909	0.945	0.991
0.130	0.046	0.245	0.151	0.360	0.296	0.475	0.463	0.590	0.634	0.705	0.790	0.818	0.913	0.950	0.993
0.140	0.053	0.250	0.156	0.365	0.303	0.480	0.470	0.595	0.641	0.710	0.796	0.822	0.916	0.960	0.995
0.150	0.061	0.255	0.162	0.370	0.310	0.485	0.478	0.600	0.648	0.715	0.803	0.826	0.920	0.970	0.997
0.154	0.064	0.260	0.168	0.375	0.316	0.490	0.485	0.605	0.655	0.720	0.809	0.830	0.923	0.980	0.999
0.158	0.067	0.265	0.174	0.380	0.323	0.495	0.493	0.610	0.662	0.725	0.815	0.834	0.927	0.990	1.000
0.162	0.070	0.270	0.179	0.385	0.331	0.500	0.500	0.615	0.669	0.730	0.821	0.838	0.930	1.000	1.000

In order to be able to apply to the new tanks the geometrical volume method of calibration, this article carries filling coefficients for cylindrical bottoms K_c, tabulated with respect to the ratio of the height of tank filling H (height of "pouring") to its diameter D. The required volume of the liquid at any level in cylindrical bottoms [4] is equal to:

$$V_f = \frac{8}{3}R^3 - 4y\left(R^2 - \frac{y^2}{3}\right), \quad (1)$$

where R is the internal radius of the cylindrical bottom; y is the vertical distance from the axis of the tank to the surface of the liquid (positive in the downward and negative in the upward direction).

If the volume of the liquid in the bottom is expressed in terms of the cylindrical bottom filling coefficient K_c and the ordinate y (see figure) we shall obtain:

$$K_c = 0.5 - 0.75\frac{y\left(R^2 - \frac{y^2}{3}\right)}{R^3}. \quad (2)$$

The volume of liquid in the cylindrical bottoms is:

$$V_f = 2K_c V_c . \quad (3)$$

where V_c is the volume of one of the cylindrical bottoms equal to $8/3 \cdot R^3$; K_c is the filling coefficient of the cylindrical bottoms calculated from (2).

The values of the coefficient K_c are given in the table with respect to ratios H/D.

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MEASUREMENT OF LIQUID AND GAS FLOW

CONSUMPTION-MEASURING DIFFERENTIAL MANOMETERS WITH AUTOMATIC CORRECTION FOR SEVERAL GAS PARAMETERS

M. D. Gafanovich

The measurement and automatic control of gas discharges is one of the important components in the working of various thermotechnical installations such as open-hearth and blast furnaces, boilers, etc.

The method of measuring gas discharges by means of pressure differences in constricting devices is the most widely used among existing methods in our industry.

In many practical cases it is necessary to measure with considerable accuracy gas discharges involving continuous automatic correction of the readings for conditions of normal temperature, pressure, and humidity by means of special flowmeters. Such flowmeters can be divided structually into three groups (Fig. 1):

1) Devices for measuring various gas parameters and converting the measuring results into mechanical, pneumatic, and similar quantities.

2) Computers which carry out the required mathematical treatment of the measurement results and adjust them to normal conditions (20°C, 760 mm Hg).

3) Devices for the transmission of results, in the form of signals proportional to the flow (in m^3/hr STP) to other instruments working in conjunction with the flowmeters.

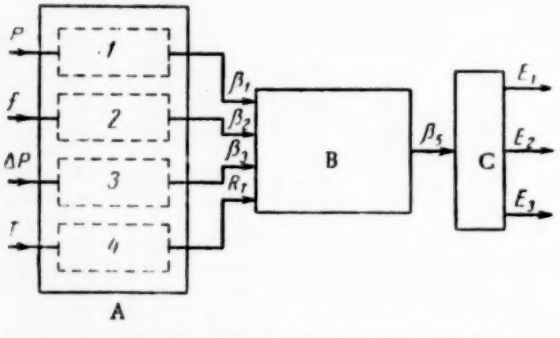

Fig. 1. Block schematic of a flowmeter with corrections. A) Measuring device; 1) manometer; 2) moisture content setting device; 3) differential manometer; 4) resistance thermometer; B) computer; C) result transmitting device.

Work on the development of automatic correction flowmeters is being conducted both in the Soviet Union and abroad.

The flowmeter and regulator with automatic correction of several gas parameters, developed by the Central Automation Laboratory of "Énergochermet" [1], uses a bridge circuit with slide wires as a computing element. A similar computing device is used in the compensation flowmeter with automatic correction for temperature and pressure of the American firm, the Bailey Meter Company [2].

The flowmeter computing device of the German firm Siemens is different, but it also uses a slide-wire bridge circuit for temperature and pressure correction.

It should be noted that computers with sliding-contact resistors are unreliable, since the resistors wear rapidly, and the contact surfaces often oxidize and become dirty, especially in the gas-filled and dusty atmosphere of chemical and metallurgical plants.

The ring-type flowmeter computing device of the American firm Hagan, is based on intricate and accurate kinematic couplings between mechanical elements resulting in considerable technological difficulties.

The problem of designing automatic correction flowmeters without sliding-contact resistors has been solved by the Khar'kov "KIP" plant.

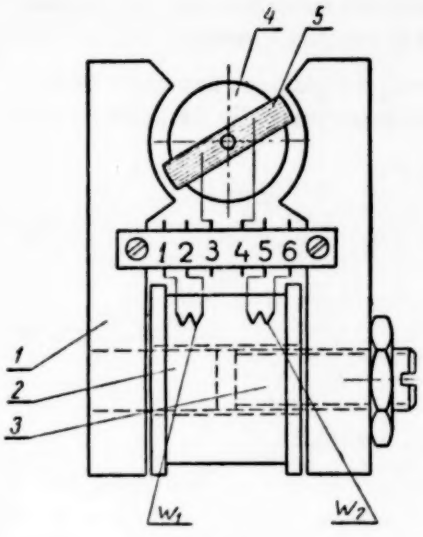

Fig. 2

Two versions* of these instruments have been developed** and are now passing their field tests:

1) DMKK, a compensation, diaphragm, high-speed, differential pressure flowmeter with automatic correction for gas pressure and temperature.

2) DMKV differs from DMKK by having an additional correction for moisture content in the gas with a manually set reference level.

The description of the more intricate instrument DMKV is given below; it includes the following measuring devices (Fig. 1): a) a manometer which registers gas pressure P and converts it into a proportional angle of rotation β_1; b) a moisture content setting device which provides angle β_2 proportional to set gas-moisture content f; c) a differential manometer which supplies angle β_3 proportional to the pressure difference ΔP; d) a resistance thermometer whose resistance R_T is proportional to the gas temperature T.

The computing devices of the instrument provide an angle of rotation β_5 which is proportional to the gas flow referred to normal conditions.

The quantity β_5 is fed to the result transmitting device which produces ac emfs E_1, E_2, and E_3, proportional to the gas flow. These emfs are output signals and are transmitted to devices working in conjunction with the instrument.

Ferrodynamic transducers, developed by the plant, are used as contactless converters of the angle of rotation into a proportional emf. A ferrodynamic transducer (Fig. 2) consists of a core, 1, with fixed, 2, and adjustable, 3, plungers working inside excitation windings W_1 and W_2. Coil, 5, is made free to rotate round the central core, 4. When an ac current is connected to winding W_1, a flux is induced in the core which in turn induces an emf in the coil. The value of the emf at the output of winding W_2 and the coil connected in series is proportional to the flux, and hence the excitation current, and the angle of rotation of the coil. The value of the flux can be adjusted by means of plunger, 3, with a constant excitation current connected to the input.

The helical spring, whose turning is proportional to the measured pressure and is transmitted to the coil of the ferrodynamic converter, serves as the sensing element of the instrument. The basic error of the manometer does not exceed ±1.5% of the maximum measurable pressure.

For convenience of calibration and checking, the manometer is supplied with an appropriate scale.

The schematic of the diaphragm, compensation, differential manometer is shown in Fig. 3.

Under the effect of the pressure difference the sluggish diaphragm, 2, placed in the body, 1, of the instrument, is displaced together with plunger, 3, which is connected to it and belongs to the differential transformer transducer, 4. The unbalanced voltage is fed to the input of amplifier, 5, which drives a capacitor induction motor, 6, linked by linear law templet, 7, to lever, 8, which operates through packing bellows, 9, the balancing spring, 10. The compensation process is completed when plunger, 3, and the diaphragm return to the initial position. The force exerted by the diaphragm is thus balanced by the spring, and the axis of the templet and the pointer are rotated through an angle proportional to the pressure difference whose value can be read (in percent) from scale 11. The templet axis is kinematically connected to the coil of the ferrodynamic converter, 12. The rotation angle of its coil is proportional to the pressure difference.

The basic error of the differential manometer does not exceed ± 1% of the full scale deflection.

* The instruments have not passed state tests.

** Registration certificate No. 11253 of November 6, 1958. The instruments were developed by K. I. Didenko, M. D. Gafanovich, V. M. Kovalev, V. A. Sushin, Zh. A. Guseva, N. G. Federova, and B. Ya. Gorodetskii.

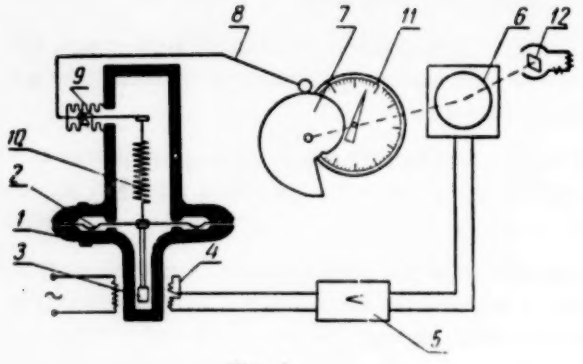

Fig. 3

For a sudden change of pressure difference from 0 to the maximum the manometer pointer traverses the whole scale in less than 2 seconds.

In measuring the gas flow, instrument DMKV continuously solves automatically the following equations [3]:

$$Q_n = K\sqrt{\frac{\Delta P K_p}{K_T K_f}}, \qquad (1)$$

where

$$K_p = \frac{P}{P_d}; \quad K_T = \frac{T}{T_d};$$

$$K_f = \frac{(\gamma_n + f)\ (0.749 + f)}{(\gamma_n + f_d\ )(0.749 + f_d\ )};$$

Q_n is the gas flow under normal conditions, nm^3/hr; K_p is the pressure correcting coefficient; K_T is the temperature correcting coefficient; K_f is the moisture content correcting coefficient; γ_n is the specific gravity of dry gas under normal conditions, kg-wt/m^3; P is the static gas pressure under working conditions, kg-wt/m^3; P_d is the static pressure assumed in designing the diaphragm, kg-wt/cm^2; T is the gas temperature under working conditions, °K; T_d is the gas temperature assumed in designing the diaphragm, °K; f is the moisture content of gas under working conditions referred to dry gas, kg-wt/nm^3; f_d is the gas moisture content assumed in diaphragm design, kg-wt/nm^3; 0.749 is the specific gravity of water vapor under normal conditions, kg-wt/m^3.

The equations solved by instrument DMKK differ from those under (1) by the absence of coefficient K_f.

When P, T, and f equal their design values $K_p = K_T = K_f = 1$, the instrument operates like a normal differential flowmeter.

The schematic of the computing and transmitting devices of the DMKV instrument is shown in Fig. 4.

The coil of converter, 1, is turned by means of a manometer through angle β_1 which is proportional to gas pressure P in the operating condition and hence to K_p, i.e.,

$$\beta_1 = k_1 K_p. \qquad (2)$$

Since the core of converter, 1 (similar to the cores of the remaining converters) works in an unsaturated condition, the emf E_p taken off its output is

$$E_p = k_2 U_c \beta_1 = k_3 U_c K_p, \qquad (3)$$

where U_c is the supply voltage which feeds the excitation winding of the converter.

The difference between E_p and the feedback emf E_{fb} is fed to the input of the electronic repeater unit (ERU) consisting of a power amplifier with a large negative feedback. E_{fb}, obtained from the feedback of converter, 2, is proportional to the excitation winding voltage, which is a part of the ERU output voltage U_{out}, and to the angle of rotation β_2 of the converter coil, i.e.

$$E_{fb} = k_4 U_{out} \beta_2. \qquad (4)$$

The coil of converter, 2, is turned by means of a handle to a preset value of the working gas moisture content f represented by an angle proportional to K_f

$$\beta_2 = k_5 K_f. \qquad (5)$$

• $nm^3 \equiv m^3$ (STP).

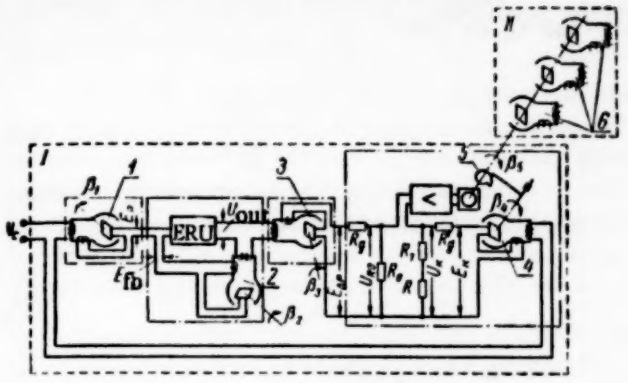

Fig. 4

It follows from (4) and (5) that:

$$E_{fb}=k_6 U_{out} K_f. \tag{6}$$

The voltage at the ERU output is equal to:

$$U_{out}=K_y\,(E_p-E_{fb}), \tag{7}$$

where K_y is the gain of the amplifier.

Thus, we obtain:

$$U_{out}=\frac{k_5 K_y U_c K_p}{1+k_6 K_y K_f}. \tag{8}$$

A quantitative analysis of the right-hand side of the denominator of (8) shows that $1 \ll k_6 K_y K_f$ and, therefore, it is possible to neglect unity with an error not exceeding 0.023%. Then

$$U_{out}=k_7 U_c \frac{K_p}{K_f}. \tag{9}$$

The coil of converter, 3, is turned by the differential manometer through angle β_3 which is proportional to the pressure difference ΔP, i.e.

$$\beta_3=k_8 \Delta P. \tag{10}$$

The emf $E_{\Delta p}$ produced by converter, 3, is proportional to the ERU output voltage U_{out} and angle β_3:

$$E_{\Delta P}=k_9 U_{out}\,\beta_3=k_{10} U_c \frac{K_p \Delta P}{K_f}. \tag{11}$$

The emf E_k produced by converter, 4, is proportional to the supply voltage U_c which feeds the excitation winding of the converter and the angle β_4 of the rotation of the coil:

$$E_k=k_{11} U_c \beta_4. \tag{12}$$

Since the excitation windings of converters 1 and 4 are fed from the same supply, the supply voltage U_c in (12) is the same as in (3).

The output of converter, 4, is loaded with stable resistors R'_g and R and resistance R_T of the resistance thermometer, which is immersed in the gas pipe line. Resistance R'_g is made sufficiently large to ensure a constant current with variations of resistance R_T due to the changes of gas temperature in the working range.

Then the voltage drop U_k across resistors R_T and R can be expressed as

$$U_k=k_{12} E_k (R_T+R). \tag{13}$$

In order to introduce an adequate temperature correction, it is necessary, as it will be shown later, to make the relative change of the total resistance (R_T + R) due to the change in temperature equal to K_T, i.e.,

$$K_T=\frac{R_T+R}{R_{Td}+R}, \tag{14}$$

where R_{Td} is the resistance of R_T corresponding to the design temperature.

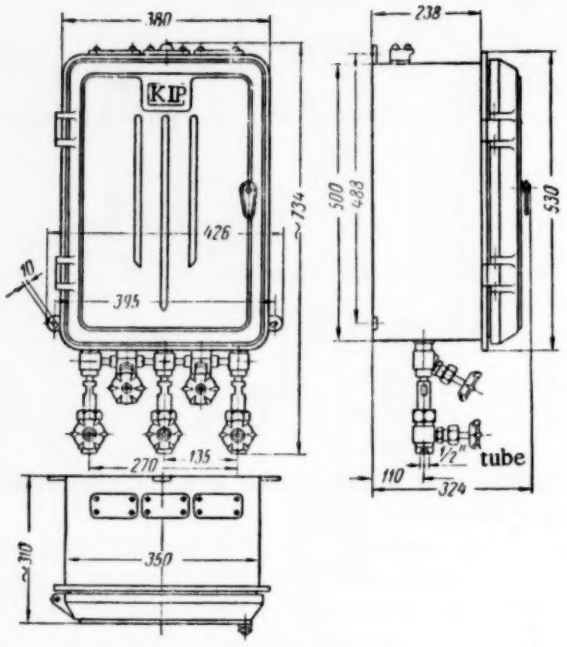

Fig. 5

Taking (14) for two values of temperature T_1 and T_2, we find:

$$R=\frac{K_{T_2}R_{T_1}-K_{T_1}R_{T2}}{K_{T1}-K_{T2}}. \qquad (15)$$

Denoting $R_{Td} + R$ by k_{13} and solving simultaneously (12), (13), and (14), we obtain:

$$U_k=k_{14}U_c\beta_4K_T, \qquad (16)$$

where $k_{14} = k_{11}k_{12}k_{13}$.

Voltage drop U_{R0} across resistor R_0 is equal to

$$U_{R_0}=k_{15}E\Delta PR_0=k_{16}U_c\frac{K_p\Delta P}{K_f}. \qquad (17)$$

where

$$k_{16}=k_{10}k_{15}R_0.$$

Resistance R_0 is made equal to $R_{Td} + R$. At the point of balance $U_k = U_{R0}$. Then we obtain from (16) and (17):

$$\beta_4=k_{17}\frac{K_p\Delta P}{K_TK_f}. \qquad (18)$$

It follows from (18) that the angle of rotation of the converter coil, 4, is proportional to the expression under the root in (1), moreover, it is independent of the supply voltage.

The profile of templet, 5, is chosen to make the axle turning angle equal to

$$\beta_5=\sqrt{\beta_4}=k_{18}\sqrt{\frac{\Delta PK_p}{K_TK_f}}, \qquad (19)$$

i.e., angle β_5 is proportional to the flow Q_n.

The axle of templet, 5, is connected kinematically to the coils of the ferromagnetic converters, 6, which produce emfs proportional to Q_n for transmission to a secondary regulating device, to an automatic circuit, or any other device.

These instruments can work in conjunction with secondary compensation devices of the VF type, electrohydraulic regulators REG, and other equipment based on ferrodynamic converters.

The instrument is cased in a dust-and spray-proof body designed for wall mounting.

It was pointed out previously that the instrument automatically corrects for the gas moisture content when the value of the content is set manually. A change to an automatic setting of the moisture content will not require any alterations in the instrument design; such a change cannot, however, be made at present since there are no simple and reliable instruments which can measure continuously the moisture content.

The "KIP" plant has developed a technique for testing the differential flowmeters with automatic correction. The relative error of these instruments is expressed, similarly to ordinary differential manometers, in percentage of the maximum measured pressure difference.

The basic error of the DMKV flowmeter is determined in the following manner.

The manometer and differential manometer are fed with appropriate pressures and pressure differences controlled by reference instruments.

The pressure (determined by the reference manometer) and the moisture content (from the scale) are set to their designed values. The external terminals of the instrument are connected (instead of the resistance thermometer) to a resistance box which is set to a resistance equal in value to that of the thermometer for the design temperature. By varying the pressure difference, the pointer is set to the required flow scale graduations and the pressure difference checked on the reference differential manometer. The absolute value of the basic error is determined as the difference between the calculated pressure difference value corresponding to the set graduation on the scale and the reading of the reference manometer.

Tests have shown that the basic error of DMKV and DMKK instruments does not exceed ± 1.5%. The additional error due to the deviation of the values of P, T, and $\underline{f}$ from their values taken for the design of the diaphragm does not exceed ± 2.5%. Thus, the total error of the instruments does not exceed ± 4%.

The technique of determining the total error of the DMKV flowmeter consists of the following. The manometer is fed with pressure P' equal either to the upper or the lower pressure correction limit. The moisture content scale is set to quantity f' equal either to the upper or the lower moisture content correction limit. By means of the resistance box, a resistance is set which corresponds to the thermometer resistance at temperature T' equal either to the upper or the lower temperature correction limits. Pressure difference ΔP which it is necessary to feed to the differential manometer in order to set on the scale of flow value 50% of the maximum is determined from the reference instrument. The pressure difference value thus obtained is then compared with the one calculated from formula

$$\Delta P = 25 \frac{K_T K_f}{K_p} \%, \tag{20}$$

which has been derived from (1) for K = 10 and Q_n = 50%.

The values of K_T, K_f, and K_p in (20) are determined from P', T', and f'.

The absolute value of the total error is defined as the difference between the pressure difference values measured on the reference instrument and calculated from (20) expressed as a percentage of the maximum pressure difference measured by the manometer.

The total error is determined for various combinations of the limiting values of P', T', and f'.

The basic technical characteristics of the DMKV and DMKK instruments are:

1. The ranges of pressure difference measurements are 0-100 and 0-1600 mm of water column and 0-40 and 0-160 mm Hg.

2. The ranges of corrections for the absolute static pressure are: 0-6, 5-11, 7-17 kg-wt/cm^2.

3. The temperature correction range is ± 50°C from the reference temperature, providing it is within the measuring range of the copper or platinum resistance thermometers used.

4. The moisture content correction is in the range of 0-50 g-wt/nm^3 of the dry gas value (only for the DMKC instrument).

5. The basic measurement error for the design values of P, T, and $\underline{f}$ does not exceed ±1.5% of the maximum measurable pressure difference.

6. The total measurement error with a deviation of the values of P, T, and $\underline{f}$ from their design values within the correction range does not exceed ± 4% of the maximum measurable value of pressure differences.

7. The time taken by the pointer to traverse the whole flow scale when the pressure difference changes suddenly from 0 to the maximum, or vice versa, does not exceed 2.5 seconds.

The overall and connection dimensions are shown in Fig. 5.

These instruments have been in use at the open hearth furnaces of the Dzerzhinskii "Zaporozhstal" metallurgical plant where they are being used for controlling the flow of oxygen which intensifies the burning.

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MEASUREMENTS OF SMALL CONSUMPTIONS OF MAZUT

K. I. Didenko and V. M. Levin

According to the Seven-Year Plan for the development of the USSR national economy, the production and consumption of oil and its products will be increased. It is known that the share of oil, its products, and natural gas in the total fuel production will form 51% by 1965 instead of the 31% it formed in 1958.

The instrument-making industry must provide high quality, modern instruments for the automation and control of ovens working on mazut. As reported in [1], the Khar'kov "KIP" plant has mastered the production of several types of piston mazutmeters for the higher measuring ranges from 500-4000 liters/hr.

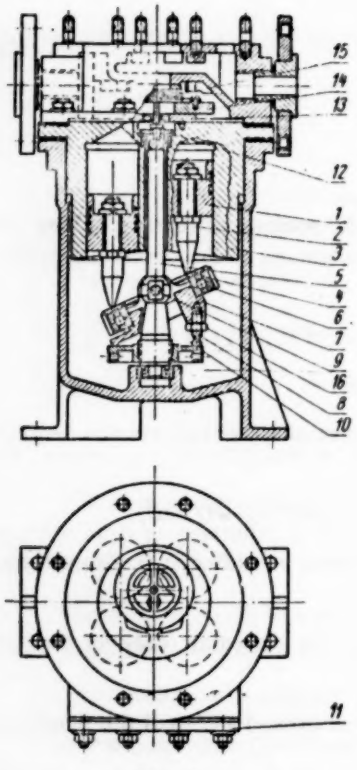

Fig. 1

However, for several years the industry has been in need of the low value flowmeters with an upper limit of 250 liters/hr to 50 liters/hr. The change-over to group mechanization and automation requires the installation of measuring and controlling equipment in small ovens. The requirement in very small value mazut flowmeters is answered by the introduction of new models of small thermal units. These units are equipped with special burners which work at low fuel consumption (sectional high-speed ovens, through and tunnel ovens, and others with a small operational volume).

Till now, instruments for such small flows did not exist.

Electromagnetic flowmeters which provide measurements of negligibly small flow and are widely advertised abroad, cannot be used for measuring liquid-containing hydrocarbons, owing to their large resistivity.

The Khar'kov "KIP" plant produced a low consumption volume meter for liquid supplied with a flow-measuring device.

The design of an instrument for low consumptions on the basis of decreasing the size of the instrument used for medium and large flows was not successful, owing to the unsatisfactory relation between the motive and friction forces.

By means of original simplification it became possible to construct a small hydraulic motor which possessed a sufficiently smooth operation and a torque large enough to be able to use a suitable tachometric head for summing, remote transmission, and presentation of the instantaneous flow value.

At the same time the plant modernized the tachometric head of the mazutmeter by changing the rheostat system of remote transmission to a ferrodynamic one.

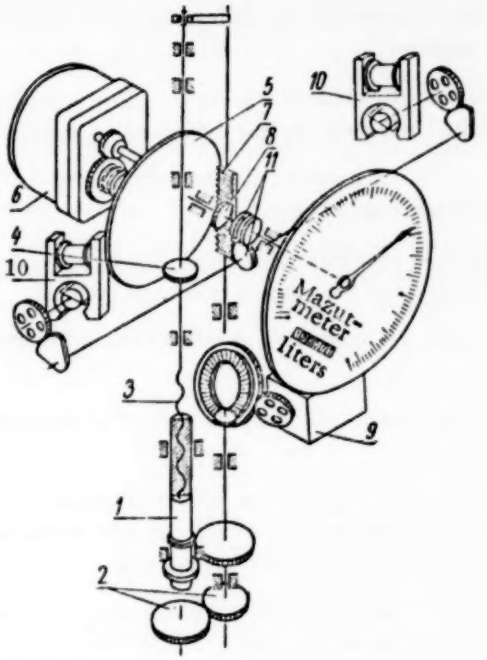

Fig. 2

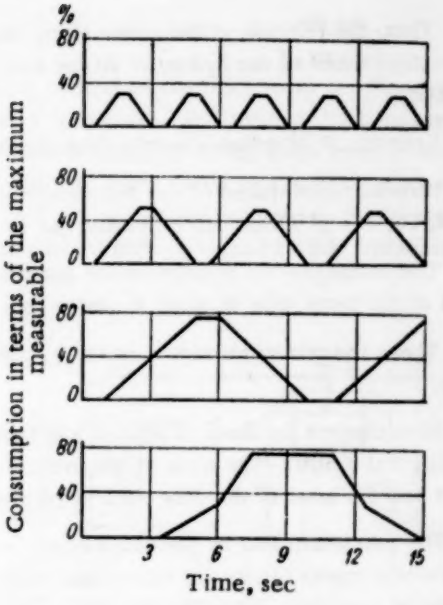

Fig. 3

Figure 1 shows the main low flow mazutmeter unit which consists of the hydraulic motor. The hydraulic motor is a device which converts the flow of liquid into a rotary movement of an axle so as to make the speed of the shaft rotation proportional to the flow of the liquid. Four pistons, 1, move in body, 3, and are rigidly fixed to coupling rods, 2, which rest against a slanting disk, 4.

The slanting disk is hinged by means of bearing, 6, and band, 7, to axle, 5. The incline of disk, 4, is set by means of screw, 8, which is secured by nut, 16.

Flywheel, 10, which is connected to axle, 5, by a fine thread serves to secure the slanting disk. The fastening of the flywheel provides a secure fixing for the entire unit.

The upper end of the central axle, 5, is fixed through crank, 12, to circular valve, 13, which slides over the top surface of the unit and opens consecutively the inlets to the hydraulic motor cylinders.

The eccentric position of the valve with respect to the axle and the appropriate shape of the distribution valve ports provide a smooth, jerkless connecting of the cylinders to the inlet and exhaust cavities of the liquid.

The valve is packed by means of a ground disk, 14, connected to bellows, 15, which separates the inlet and exhaust cavities. The connection between the disk and the valve is secured by means of helical springs.

Consecutive pressing of the coupling rods against disk, 4, makes it turn together with axle, 5, about the vertical axis of the hydraulic motor. The surface of the rod ends and the disk are heat treated and polished. Hence, owing to the lubricating properties of mazut, the sliding causes little friction. It should be noted that disk, 4, only swings but does not turn, thus greatly reducing the friction.

The slant of the disk determines the stroke of the pistons and, hence, the amount of liquid passing through the hydraulic motor during each revolution of the axle.

The calibration of the hydraulic motor is carried out by adjusting the slope of disk, 4, by means of screw, 8, and flywheel, 10, through hatch, 11.

The schematic of the mazutmeter modernized tachometric head is shown in Fig. 2.

The extended nut 1, with a coarse thread, is driven by the hydraulic motor through step-up gears, 2.

Screw, 3, is connected to the nut and carries a friction disk, 4, which is driven by disk, 5, connected to a small-size synchronous motor, 6. If the angular velocities of the screw and the nut differ, the screw with the roller will be driven up or down until their angular velocities are equalized.

Thus, the position of the screw along the vertical axis has a single value and provides a linear measure of the rotation speed of the hydraulic motor axle. By means of rack, 7, and gear, 8, this movement is transmitted to a pointer.

Counter, 9, is driven directly from the hydraulic motor through a set of gears.

Remote transmission of the instrument readings is accomplished by means of moving coil ferrodynamic converters, 10, one of which can be connected to a secondary instrument and the other to a control system.

The ferrodynamic converters are operated by a compact drive, 11, consisting of a four-turn worm-gear connected to the same axle as gear, 8, and a gear wheel.

These converters provide a reliable, contactless remote transmission free from the defects of rheostat converters.

Mazutmeters for flows of 50 and 250 liters/hr are now being mass-produced and are in operation at many metallurgical plants. The error of the total consumption of these instruments does not exceed ±2% of the recorded amount and the error of the flow indication not more than ± 2.5% of the maximum scale reading.

The maximum loss in pressure due to the instrument does not exceed 2 mm of water column. The maximum static pressure inside the instrument body is 10 kg/cm^2. Its flow measuring range is from 20 to 100%. Its threshold of sensitivity is not higher than 0.5% of the full scale reading.

A study was made of the ability of volumetric, cylindrical mazutmeters to operate with suddenly changing flows. It should be noted that in metallurgical plants and heating units in other branches of industry the consumption of mazut can change suddenly. The pulses or sudden changes can be of a random or periodic nature owing to unequal supply or technological necessity. The preservation of the accuracy of the instrument under pulsating conditions is a most valuable asset uncommon to flowmeters.

Tests of the volumetric piston flowmeters showed that they possess the important property of registering with practically the normal accuracy the total fuel consumption under widely different pulsating conditions. This accuracy was checked on special benches by the weighing method. The pulsating consumption was produced by automatic control of the inlet valve of the instrument by means of a specially constructed pulsator.

The main unit of the pulsator consisted of a reversible electrical actuating mechanism, controlled by switches. The switches were operated by means of a synchronous motor with a replaceable cam.

The control of the inlet valve was attained by means of a three-link lever arrangement, which connected the axle of the actuating mechanism with the valve.

The pulsating conditions were adjusted by mounting a cam with the appropriate number of lobes which determined the frequency of pulsation and by regulating the lengths of the three-link device.

Figure 3 shows the most characteristic conditions of pulsation with periods from 15 to 3 seconds.

Tests have shown that the error in measuring the total consumption by means of mazutmeters due to pulsating conditions does not exceed 0.5% of the amount measured. This property of the instrument can be very useful in many branches of industry.

The voltmetric mazutmeters do not cover as yet the whole range of measurements required by industry. Many organizations and plants persistently request the supply of instruments covering the range of flows from 5 to 25 kg/hr. Such an instrument is being at present developed by the special design office of the plant. Its eventual introduction will provide a further economy in the utilization of fuel, will decrease the burning of metal, and improve the heating efficiency of small size ovens.

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MEASUREMENT OF SMELTING LEVELS

B. A. Glagovskii

In laboratory investigations of high temperature melts a precise control of the melt level is often required. Such a control is important in studying melts of glass, resins, and other substances. For instance, the measurement of viscosity of these substances by Stokes' method [1] requires a precise knowledge of the melt level at every instant. The knowledge of levels is also required in measuring the density of these melts and in various other experiments. Apart from the above laboratory measurements of levels, their control is also required in production, for instance, directly in a glass furnace, in vessels for resin smelting (in optical production), and other instances of preparation and use of melts.

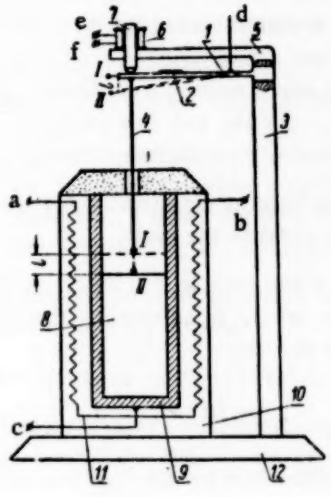

Fig. 1

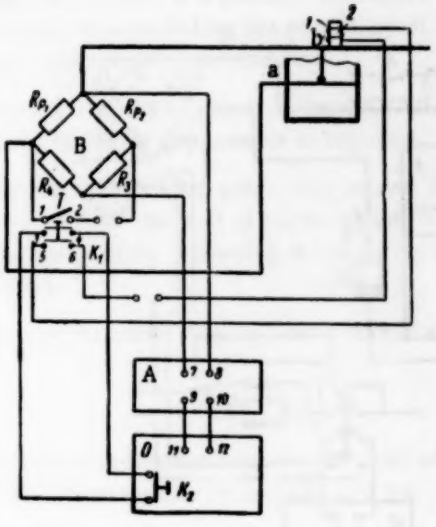

Fig. 2

Common level indicators used in measurements (including level indicators operating on the basis of radioactive isotopes [2]) cannot solve the problem of measuring melt levels at high temperatures, since these melts must be placed, in order to retain their high temperature, in special containers (crucibles) inside ovens or thermostats. The use of conventional level indicators inside ovens or thermostats (especially, if their walls are thick) is impossible.

These considerations led to the necessity of using in these cases special level indicators, which can also be used for measuring levels of various liquids at high temperatures and placed inside thick-walled containers. The instrument we are going to describe is based on strain-gage transducers.

The schematic of the instrument is shown in Fig. 1. Measuring blade, 1, with transducers, 2, glued to it, is carefully fixed at one end to stand, 3. The free end of the measuring blade holds pin 4. For measuring high-temperature melts the pin is made of platinum.

Electromagnet, 6, with core, 7, is placed on bracket, 5, attached to stand, 3. Melt, 8, whose level is being measured, is contained in vessel, 9 (at high temperatures in a platinum or quartz crucible), placed inside oven, 10, with heater, 11. The lead-out wires a and b of the heater are connected to the line. Both the oven and stand, 3, are fixed to base, 12. When a photoelectric viscosimeter is used [1] the level indicator is mounted on the meter itself as an additional unit.

Two types of instruments are made: manually (Fig. 2) and automatically operated.

One of two sensing transducers (R_{p1} and R_{p2}), depending on the sensitivity required, are glued to blade, 1 (see Fig. 1). The use of two transducers doubles the sensitivity of the circuit, according to the theory of bridge

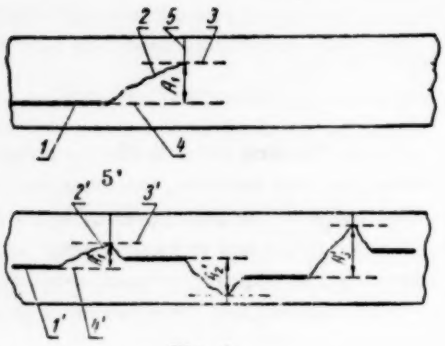

Fig. 3

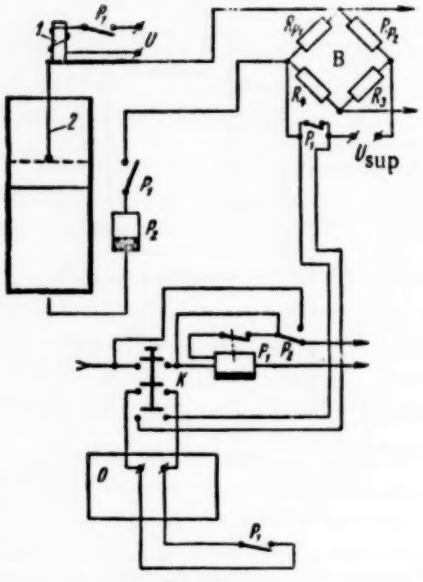

Fig. 4

circuits [3], and provides the required temperature compensation.*

The instrument works in the following manner: the operation of tumbler switch T (closing contacts 1-2) connects supplies to the bridge circuit $R_{p1}-R_{p2}-R_3-R_4$, and the chart-drive mechanism of the oscillograph** is started by pressing push-button switch K_2.

Zero line 1 (Fig. 3) is recorded on the film (paper). The zero line corresponds to the unloaded condition of the measuring blade, 1 (Fig. 1). Contacts 3-4 and 5-6 are closed by means of the push-button switch K_1 and electromagnet 1 energized, whose armature, 2, moves the measuring blade. The oscillograph (ink recorder) registers the bending of the measuring blade's free end, thus producing line, 2, shown in Fig. 3. When the measuring pin, 4, reaches the melt level (Fig. 1) the circuit (shown by a thick line) is closed across terminals c-d (Fig. 1) or a-b (Fig. 2). This circuit shunts sensing transducer R_{p1}, completely unbalancing the bridge circuit, and thus producing a sharp deflection on the oscillogram (see position 5 in Fig. 3).

Amplitude A_1 defined as the distance between 3 and 4 determines uniquely the level of the melt.

The measuring blade with its transducer is calibrated directly in units of the level. In calibrating the level indicator the following curve is plotted:

$$p=f(l),$$

where l is the level difference (or the displacement of the measuring blade end); p is the output parameter of the circuit (for instance, the output current).

The bending, l, of the measuring blade corresponds to the distance I–II*** covered by the pin (Fig. 1), thus providing a measure of the level variation.

The recording instrument reads directly in units of level since its calibration is made over the whole circuit including amplifier A and oscillograph O.

The circuit can be easily made automatic without any alteration of the instrument itself. It is only necessary to add an attachment (relay unit) to it.

The operation of the automatic version of the instrument is shown in Fig. 4.

The operation of push-button switch K connects the supplies to oscillograph O, bridge B, and slow-operating relay P_1. Oscillograph O starts drawing the zero line (1' in Fig. 3). Relay P_1 operates (push-button K is by then released) and closes all its contacts as shown on the drawing and locks itself in the operating position (through its own contact). The contacts of relay P_1 retain the supplies of the bridge and the oscillograph chart-driving mechanism and connect the supplies to electromagnet, 1, and prepare for operation the circuit of relay P_2. Similarly

* When one sensing transducer is used $i = I\frac{\Delta R}{R_t}$ and with two $i = I\frac{\Delta R}{2R_t}$ where R_t is the transducer resistance; ΔR is the resistance increment, I is the supply current, and i is the output current.

** Various vibrating oscillographs and ink recorders can be used as registering devices; provision is also made for the use of pointer instruments for visual observation.

*** Position I can be varied by using pins of different lengths.

to the first type level indicator, the deformation of the transducer produces a certain unbalance in the bridge and the unbalance voltage is fed through terminals 7 and 8 to the amplifier (Fig. 2) and then (via terminals 9 and 10) to the oscillograph which records line 2'. As soon as the measuring pin touches the melt, relay P_2 operates (the contacts of relay P_1 have prepared the required circuit). Relay P_2 is also slow operating. Relay P_2 opens its contact in the blocking circuit of relay P_1 and closes the supply circuit of the latter relay. Relay P_1 releases (owing to the opening of its blocking) and opens its contacts (including the one in the P_2 supply circuit); relay P_2 releases and restores the blocking circuit of relay P_1, which then operates. The shunting of the sensing transducer (similarly to the first type level indicator) produces a deviation 5' of the recording line (Fig. 3). The releasing of relay P_2 after the operation of P_1 repeats the recording cycle on the oscillogram at intervals A'_2, A'_3, etc.

Quantities A'_1, A'_2, and A'_3, similarly to the instance described first, represent uniquely the level of the liquid (melt).

Adjustment of the operating time of relays P_1 and P_2, which constitute a pulsating pair, provides a reliable operation of the instrument. With a slow recording speed and a long film (paper) it is possible to obtain a continuous recording for 3 hours, and with special rolls for a much longer period, thus providing the possibility of measuring the level not only for experimental or research purposes but also under production conditions.

The recording can be made by means of highly sensitive vibrators directly on the oscillograph without the use of amplifiers. The circuit also provides for the use of mechanical recording instruments as registers.

Under laboratory conditions the levels are measured in millimeters, whereas in production control the unit employed is the centimeter. When amplifiers are used, the change-over from one unit of measurement to the other is accomplished by switching over to a less sensitive range (for instance, by increasing the negative feedback, which also increases stability and decreases the error of the amplifier).

The systematic error of the entire measuring circuit is eliminated by calibration against a level indicator with a standard measuring channel.

The calibration is made in level units.

When an oscillograph with a moving-coil vibrator and an instrument amplifier are used, the error of the instrument amounts to about 2%. By means of special measuring circuits this error can be reduced to 1.5%.

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MATERIAL RECEIVED BY THE EDITORIAL BOARD

THE ORGANIZATION AND ACTIVITY OF INDUSTRIAL TEST LABORATORIES

(COMMENTS ON K. N. KATSMAN'S ARTICLE *)

A. I. Suvorov, Chief Engineer of the Ivanovo Inspection Laboratory of Measuring Equipment

In order to ensure the fulfillment of the Seven-Year Plan for a further expansion of industrial production and construction work, a rise in the quality of commodities, and a lowering of the cost of production, the June Plenum of the CPSU Central Committee indicated a course of development for each branch of the national economy, including the introduction of group mechanization in industry and construction work, automation of production, setting up of transfer lines, and the replacement of obsolete equipment, jigs, and tools by new ones.

In the struggle for technical progress, in the production of new commodities, machines, and materials, in developing new and improving existing technological processes an active role must be played by the scientific research institutes, design bureaus, factory and plant laboratories.

In his article "Certain problems of organization and activity of Industrial Test Laboratories" K. N. Katsman raises important and pressing problems of organization and activity of test laboratories in factories.

Actual experience decisively confirms Katsman's opinion that many industrial test laboratories are divorced from production, confined to the narrow limits of testing, do not pay sufficient attention to introducing new gage inspection methods, do not render the required assistance to technologists in choosing the best means and methods of inspection and in developing new and perfecting existing technological processes and in making production automatic.

Test laboratories are in possession of extensive material regarding dimensional and other rejection of components, semifinished production, and finished articles, owing to their functions as inspection agencies, yet very often they do not sort out or analyze this material: they simply record rejections but take no measures to avoid them; they do not, for instance, conduct any experimental work in order to find the basic causes of dimensional rejections.

The work of industrial laboratories in disseminating among the workers the skill and habits of correct maintenance and use of measuring equipment is sadly neglected. Yet the quality of large-scale mass production should be ensured, in addition to inspection, by certain organizational and technical measures, the most important and essential of which is the raising of the worker's responsibility for the quality of production and the reduction of the inspection personnel to the minimum.

These functions of the laboratories are very important and pressing, but one should not belittle, as Katsman does, the laboratories' inspection activity intended to maintain a uniform, efficient, and correct application of the measuring equipment and provide interchangeability of components, units, and mechanisms in finished production. The relegation of this function, whose fulfillment occupies the greater part of the laboratory personnel's working time, to a secondary place only because "in the best case it would only sustain the level of technical measurements already achieved," appears to us to be insufficiently convincing. In fact, there are many laboratories which

* Izmeritel'naya Tekhnika No. 4 (1959). [See English translation.]

have not attained the modern level of technical measurements. For such laboratories the main task should consist in achieving this level, and in cases where it has already been attained, to maintain and further develop measuring techniques to the full satisfaction of the growing demands of production.

The exercise of the inspection function by the laboratories includes and predetermines other functions, hence inspection is not a secondary,but one of the main functions of a laboratory. This approach will also fully ensure correct test results and methods of quantitative evaluation of physical and mechanical values, which, according to K. N. Katsman, are main functions of the Industrial Test Laboratories.

At the same time,K. N. Katsman considers that the creative initiative of the laboratory personnel should be directed towards finding "white spots" in production, i.e., production processes which require but do not possess gages for the evaluation of physical quantities.

We think that such an approach to the work of test laboratories is incorrect, since it belittles the functions of the technical departments and technologists, whose work includes the complete working out and improvement of technological processes, as well as the selection and assignment of the means and methods of control by means of gages and the fixing of tolerances in technical measurements. Obviously this does not include, but it presupposes the duty of the laboratories to render assistance to the technologists in the selection of efficient means of control of technological processes and in compiling plans for introducing new and replacing obsolete measuring equipment at each production stage.

Katsman states that industrial laboratories should at least be able to compile completely requirements for the design of new instruments necessary in a given branch of production and should insist on their implementation by the organizations concerned.

This function, however, is to a greater extent the concern of technical departments and technologists and not test laboratories, since the former can take into consideration the peculiarities of any branch of production and determine more accurately the requirements for the design of new instruments, and the test laboratories should only assist them in this task. It is sufficient for the laboratory personnel to be able to compile design requirements for test instruments and devices necessary for improving the efficiency of testing,and to be able to determine competently the advantages and disadvantages of measuring equipment on the basis of their observations and the study of the operational qualities of the measuring equipment.

It should be appreciated that assignment of new tasks to the laboratory staff will require its enlargement at the expense of the engineering personnel.

In order to stimulate a further rise in the efficiency of the laboratories and in their influence on production, it is advisable to divide them into three categories determined by their technical equipment, their functions,and their efficiency in providing technical measurements in production. Such a structural classification of laboratories will raise the initiative of the laboratory staff; laboratories of the lowest category which are on the level of Control and Checking Stations will strive to develop,in order to pass to the middle and then the top category. The transfer of laboratories from a lower to a higher category must be accompanied by their acquisition of the appropriate equipment.

Promotions of laboratories from one category to another should, in our opinion, be made on the recommendation of State Inspection Laboratories by the appropriate Councils of National Economy. The absence of such a classification of laboratories lowers their interest in technical progress. This is confirmed by the existence of well-equipped laboratories which perform the functions of ordinary Control and Checking Stations and by the absence of interest in the technical development of laboratories on the part of the factory managements. Such a classification of laboratories is especially important for new plants, where the work of test laboratories does not receive sufficient attention.

In order to rationalize the extremely diverse organizational and technical forms and structures of test laboratories in engineering plants of the region, the administration of the engineering and chemical industry of the Ivanovo Council of National Economy worked out and introduced a regulation which establishes a general form of organization and inspection routine of measuring equipment in engineering plants of the Council.

This regulation provides the following basic functions for test laboratories of the highest category:

Periodic testing and certification of measuring equipment according to test specifications at intervals which are determined from a graph, compiled by them in conjunction with production technologists and the Technical Control Division and approved by the plant administration;

working out and supervising the application of measures for ensuring uniform and correct technical measurements at all stages of production by organizing supervision over the means and methods of measurement according to the Supervision Specifications of the Council of National Economy;

guiding the work of the Control and Checking Stations, instructing their personnel, and supervising their activity;

working out, in conjunction with the technical department, measures for ensuring control by means of gages at all the stages of production, for introducing the best means and methods of measurement, and developing test and control equipment for automation and mechanization of production;

conducting periodical practical instruction of factory workers who use measuring equipment in the correct maintenance and use of the equipment;

sorting out the data obtained in the inspection and tesing of measuring equipment, components, and finished production in order to analyze it and formulate proposals for lowering production scrap, increasing the durability of instruments and gages, improving their operational characteristics, perfecting the means and methods of control, and raising the quality of measuring equipment repairs;

formulating requirements for the design of new test equipment and conducting experimental development work with the object of proving the advisability of introducing new means and methods of measurement and inspection;

participating in working out measures for the introduction of new equipment and the modernization or replacement of the old;

developing and establishing in the plant a system of issuing certificates and warranties for the measuring equipment, and compiling schedules and graphs for checking reference measures and instruments.

The subordination of the Industrial Test Laboratories to the Technical Control Divisions is advisable since the latter are most interested in always maintaining the measuring equipment in a working and efficient condition.

K. N. Katsman's proposal to reduce the number of general inspections, made by the Committee's Agencies, of the control exercised by the plants over the condition of their measuring equipment is completely acceptable and timely, provided the quality and thoroughness of these general inspections is improved.

Workers engaged in the technology of measurement in other plants should be encouraged to participate in the inspection of the work of test laboratories and control agencies, thus providing the opportunity of conveying in a graphic and concrete manner the experience acquired by the best laboratories to those which lag behind.

I. I. Suslovich, Chief of the Central Measurement Laboratory (Dnepropetrovsk).

The problems raised in K. N. Katsman's article deserve attention. As long ago as 1940, the duties of test laboratories were specified in rules 10-40 of the Committee of Standards, Measures, and Measuring Instruments.

According to paragraph 24, test laboratories are entrusted with:

. . . g) Developing measuring methods and checking the means of measurement required by a plant, and also introducing the best of automatic instruments and methods of inspection of components in production shops.

h) Controlling the correct allocation of measuring means in the technological charts and giving advice and assistance to the technical department with respect to the choice and application of measuring equipment.

Test laboratories either ignore or fulfil only partially these two important instructions, which cannot be considered as satisfactory. The reason for this state of affairs is the incorrect organization and subordination of these laboratories. This is incontestable. Katsman is incorrect, however, in proposing to unite all the test laboratories into one central laboratory subordinated to the chief engineer of the plant. The reasons given by Katsman for the

advisability of this fusion are not convincing. If electronics invade linear measurements it does not mean that linear measurements should be amalgamated with radio measurements. It is known that linear instruments for measuring angles are based on mechanical, optical, electrical, radio, pneumatic, chemical, and other laws. This does not, however, hinder in the least the linear measurement specialists from bringing into use new instruments. The difficulty of introducing new production instruments and new methods of inspection lie in the conditions of subordination of the laboratories.

Technological processes in the manufacture and control of components are worked out in engineering plants by the Chief Technician's Department, whereas the linear and angle measurement laboratories are in the Technical Control Department. Thus, the Central Measurement Laboratory (TsIL) does not take part in determining the technology of production. In the best case, technologists can apply to the Central Measurement Laboratory for advice on certain measurement problems. If the Central Measurement Laboratory were subordinated to the Chief Technician of the plant, it would have to satisfy different demands and its structure would change correspondingly. The same applies to other test laboratories. It follows, therefore, that the subordination of the laboratories should be altered in such a manner that they become more useful to production.

Katsman considers that the main task of test laboratories does not consist in maintaining unified measurements, or even in supervising the state of the test equipment, but in ensuring by all the means at their disposal the accuracy of measurement results and methods of quantitative estimation of physical values in production, both by studying them on the spot and using at all production stages, accurate, reliable, cheap, and productive means and methods of measurement. This is incorrect, since it is impossible to consider as secondary such an important task as the preservation of unified measures, without which it is impossible to operate a single engineering plant. It is well known what role the test laboratories have played in establishing our engineering, instrument making, aircraft, and other industries by fulfilling precisely this task.

Introducing in production accurate, reliable, cheap, and productive methods and means of measurement in engineering plants is one task of the Chief Technician's Department. Test laboratories should take an active part in this work, and this is only possible if they are subordinated to the Chief Technician of the plant. Test laboratories cannot solve this question independently as their main task.

Yet another question arises: Will the linear and angle measurement laboratories be able to preserve the unified measures, etc., which is their basic function, while outside the Technical Control Division of plants? They will undoubtedly be able to do it. At present, laboratories in other spheres of measurement are fulfilling such functions although they belong to other departments of the plant.

In fine, I should like to express the wish that after discussion of this question a decision binding all establishments be rapidly adopted.

M. N. Poltenberg, Chief of the "Progress" Plant (Berdichev) Test Laboratories

Katsman incorrectly describes the work of the majority of test laboratories in our country, taking the desirable for the actual. The conditions of work of the majority of individually producing and small-scale mass producing plants are very diverse and the field of action of laboratories, especially linear and angle measurement laboratories, is very extensive.

Yet can the principal sphere of their activity be what K. N. Katsman suggests in the following passage, "The basic task of test laboratories should be neither the maintenance of unified measures nor even supervision of equipment, but a provision, by all possible means, of accurate technical test results"? How is it possible to obtain accurate technical test results without ensuring unified measures?

K. N. Katsman's proposal to amalgamate all the laboratories is not correct. What is there in common between an electrical laboratory and linear and angular measurements? Katsman, it would appear, is pleased that "optics and mechanics is invaded by electronics." This is all right as far as it goes, but one cannot neglect either

the conditions of work of laboratories in different spheres or the existing possibilities. It is impossible to immediately base everything on optical, electronic or other measurements. Let all the industrial laboratories use all the best equipment they possess today, and this alone will be very satisfactory. It is first necessary to raise the measuring equipment and technique to a higher, genuinely modern level and only then think of the amalgamation of laboratories.

K. N. Katsman proposes that test laboratories should specify the measuring equipment required by any given plant. It would be more correct for the laboratory to explain to the measuring instrument or measuring equipment bureau the efficiency of a given measuring apparatus or control device, or to assist in introducing better instruments having proved superiority, etc, but in no case should it design them. Otherwise, the laboratories will meddle in somebody else's business. Katsman gives examples of the personnel of small laboratories carrying out important development work. It is desirable for individual laboratories to be engaged in creative work, without restricting themselves to a narrow sphere of activity. We have several such laboratories in our plant as well, but this does not mean that laboratories should basically reorganize their activity.

S. S. Kharlamov, Chief of the Central Measuring Laboratory in Bryansk

K. N. Katsman's article has a topical significance for the operation of industrial test laboratories at the present stage of development of our engineering and instrument-making industries. It is not by accident that this journal has also published by way of discussion comments of its readers* on B. N. Vorontsov's article entitled "Pressing problems of the Departmental Inspection Agencies" (No. 5, 1958).

The authors of these articles make a timely and correct contribution by suggesting that the work of the factory inspection agencies should be reorganized by exposing them to actual production and making them participate directly in ensuring correct results in technical measurements and methods of evaluating physical quantities in production by applying at all the stages of production accurate, reliable, cheap, and productive means and methods of measurement.

It is true that many industrial laboratories have limited themselves to testing only. In the majority of cases the responsibility for this state of affairs does not lie with the laboratories, but with the departmental barriers and the existing method of subordination of the Departmental Inspection Agencies. Moreover, it is obvious that some of the State Inspection Laboratories have not reexamined their work in the light of the decisions of the CPSU 21st Congress, and often in their one or two day general inspection affect the whole activity of the test laboratories in a manner to be expected. Many State Inspection Laboratories, and in particular the one at Bryansk, hardly ever work in conjunction with the industrial laboratories. Yet there should be systematic consultations with the personnel of the Central Measurement Laboratories (even if it were only for the purpose of exchanging experiences, and discussing the quality of the measuring equipment, classification of equipment, and instruments) and lecture classes, for raising the qualifications of the Central Measuring Laboratories' personnel, on questions of automation and mechanization of the technical control in engineering should be organized.

K. N. Katsman is correct in suggesting the amalgamation of all the plant laboratories into a single Central Measurement Laboratory subordinated to the Chief Engineer of the plant, thus providing the opportunity of solving the problems of production measurements in a practical and full manner.

At present the following laboratories exist in a plant: the TsZL (central factory laboratory) subordinated to the Chief Engineer or the Chief Metallurgist, the TsIL (central laboratory for line and angle measurements) subordinated to the head of Technical Control Division, and electrical and thermal measuring laboratories subordinated to the Chief Power Engineer; they all operate disjointedly.

It seems strange that the reorganization of industrial administration and the formation of the Council of National Economy have hardly affected the activity of the departmental inspection agencies.

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* Izmeritel'naya Tekhnika No. 2 (1959). [See English translation.]

In order to improve the structure of industrial laboratories and solve immediately the pressing problems of introducing effective means of automatic control in production, it is necessary for the Councils of National Economy to reorganize the Departmental Inspection Agencies, amalgamate the industrial laboratories into a single Central Measuring Laboratory, and determine its functions strictly in accordance with the requirements of technical progress, subordinating the laboratory to the Chief Engineer of the Plant.

INFORMATION

THE ALL-UNION SCIENTIFIC CONFERENCE ON RADIOTECHNOLOGY

WORK IN THE SPHERE OF RADIO MEASUREMENTS

An All-Union Scientific Conference dedicated to the centenary of the birthday of the great Russian scientist and inventor of radio, A. S. Popov, was held in Moscow from June 8-12, 1959.

The conference was attended by more than 2000 scientists, engineers, and technicians from Moscow, Leningrad, Khar'kov, Gor'kii and other towns of the Soviet Union as well as by several scientists – guests from foreign countries.

Among the many Conference sections there was one dealing with radio measurements, at which 30 papers were read in six sessions.

The well-known British scientist, Dr. L. Essen (National Physical Laboratory) reported on his work in establishing and investigating a cesium frequency standard. Great interest was aroused by the data referring to its use in the time service, and the report on its new construction with a lengthened vacuum tube. The participants of the conference warmly congratulated the speaker on the successful accomplishment of his important scientific work and the award of the A. S. Popov gold medal this May from the Presidium of the Academy of Sciences, USSR.

In his paper, entitled "Determining the frequency of molecular generators by time service method," A. Ya. Leikin examined a frequency standard, which consisted of two ammonia beam molecular generators, a continuously operating quartz clock, and a system of frequency comparison. The error in reproducing the absolute frequency value is determined by the error of tuning the molecular generator and is evaluated at $\pm 3 \cdot 10^{-10}$. Examples of determining the molecular generator frequency in terms of astronomical time, UT-1 and UT-2, were given; such determinations provide an opportunity of evaluating the irregularities of the earth's rotation. In the discussion on the paper it was noted that the molecular standard which was made and used in the time service improved considerably the operation of this service.

In A. G. Smagin's paper on "The prospects of raising the stability of quartz oscillators used for frequency standards," a new method of raising the stability of a quartz resonator by immersing it in a vessel with liquid helium is described. Preliminary investigations have shown that the quartz resonator Q-factor is thus raised to $\sim 86 \cdot 10^6$. Calculations have shown that the ageing at the temperature of liquid helium of quartz toroids developed for the purpose could have the value of $\sim 1 \cdot 10^{-12}$. It was shown that quartz resonators can be maintained in thermostats at a temperature of 4.2°K with an error of $\pm$ 0.001°K.

In his paper entitled "Methods of improving bar-shaped quartz resonator Q-factors up to the value of several millions," I. V. Grinenko shows that by means of higher quality of finish of crystal surfaces and using improved constructions of crystal holders and electrodes, it is possible to raise the Q-factor of these elements from $2 \cdot 10^5$ to several millions. The conference noted that the use of these high-Q quartz resonators in frequency standards will considerably increase their stability.

B. A. Finagin provides in his paper, "Degeneration of oscillations and dipole splitting of the piezoresonator's natural frequency," experimental data obtained in investigating this splitting and derives certain practical conclusions of its effect on the work of piezoelectric resonators in radio, optical, and ultrasonic equipment. It is shown that the splitting varies with resonance and is accompanied by a turning of the oscillation pattern through a certain angle corresponding to the given resonance. It has been shown that the dipole splitting of the natural frequency is the result of diminished degeneration under the effect of a small disturbance (a small anisotropy of properties or boundary conditions) of certain types of oscillations which are degenerate.

K. V. Khodataev's paper, "Measurement of the Q-factor of volumetric resonances by the comparison method" deals with a method of Q-factor measurements based on comparing the resonator under test with a standard RC circuit by means of the frequency distortions introduced by these circuits respectively in a high-frequency pulse and in its envelope. It was shown that, providing certain conditions are observed, the value of the coupling between the generator and the resonator and the shape of reacting high-frequency pulses do not affect the measurement results.

G. A. Bogdanov shows in his paper, "Investigation of the stability of a low-frequency transistor oscillator" that in a low frequency transistor LC oscillator, frequency stability depends in the main on the stable state of oscillation and also on the choice of the dc conditions.

A. G. Pokrovskii reviews in his paper, "New radio measurement instruments for general application" the instruments recently produced, including voltage and power meters, UHF and pulse measuring instruments, and oscillographs, measuring amplifiers, signal generators, frequency analyzers, etc.

Several papers dealt with current, voltage, and pulse measurements at ultrahigh frequencies.

V. R. Lopan's paper, entitled "Instruments for measuring current at frequencies up to 300 Mc" dealt with a newly designed ammeter consisting of a combination of a vacuum electrodynamic ammeter with a short-circuited, freely oscillating ring and a photoammeter with vacuum radial tubes. The ammeter's frequency range is 1-300 Mc and the measuring range 100 ma to 10 amp; the error of measurement does not exceed ± 0.5% of the measured quantity.

In their paper, "Experimental determination of high-frequency errors of diode voltmeters in the range of 1000 Mc", A. M. Fedorov and B. E. Rabinovich deal with high-frequency errors of a compensation voltmeter type OKV-2 with diode 2D1C at voltages of 0.1-1 v, determined by comparing its reading with those of a thermistor voltmeter. The experimentally obtained total frequency errors of the voltmeter are divided into two errors: the transit and resonance error. The Conference recommended:

a) basing the production sorting of diodes on their interelectrode distances in steps of 20-30 μ, thus considerably increasing the precision of voltage measurements and measuring the power in the meter and decimeter bands by means of correction curves;

b) to continue measuring the frequency error of diode voltmeters with the object of accumulating statistical data, which will provide a basis for specifying the requirement for the design of new measuring diodes with small interelectrode dimensions.

M. M. Levin's paper, "Measurement of high-frequency voltage pulses by means of a diode voltmeter" shows that at UHF, when the transit time of electrons between the electrodes becomes important, the frequency error of the diode voltmeter is different, when measuring pulses, from its error when measuring a continuous high-frequency voltage.

In his paper, entitled "Measurements of short pulse amplitudes," M. I. Gryaznov evaluated systematic errors in measuring short radio and video pulses. Various compensation and autocompensation voltmeter circuits are examined and compared with each other. The Conference recommended proceeding with the experimental design work in order to develop a pulse voltmeter for measuring amplitudes of short pulses.

K. G. Kir'yanov gives in his paper, "An apparatus for calibrating GSS oscillators by their output voltages in the frequency range of 0.1-1000 Mc," brief characteristics of the equipment and the peculiarities of its work with signals below the noise level. The Conference noted the importance of developing the equipment for measuring voltage ratios (such as the voltage standing-wave ratio, the modulus of the transfer constant of various quadripoles, etc.).

In their paper, entitled "A standard calorimetric device for checking low power meters in the range of 0.75-1.8 cm," A. I. Brodskii, A. N. Akhiezer, V. N. Magda, and A. P. Sen'ko describe the design of microcalorimeters which provide the measurement of powers in the range of 7.5-18 mm with an error not exceeding 1.5% for power levels of 2-100 mw, and that of devices for checking low-power meters by means of calorimeters with an additional error not exceeding ± 2% at power levels of 500 μw to 5 mw. The Conference noted that the development of microcalorimeters has solved the problem of establishing primary instruments for measuring EHF power in the millimeter range.

A. D. Selivanovskii, V. A. Yugov, V. N. Krasnopistsev, and Yu. Durasov provide in their paper, "Film bolometers for measuring SHF power" characteristics of film bolometers and bolometric heads in the range of 20,000 to 40,000 Mc and data on the construction and technology of their manufacture. These metal-film bolometers were recommended by the Conference for use in SHF power meters in the range of 10 μv to 1 w. It was also recommended that work be done on the design of untuned heads in the range of 10,000- to 40,000 Mc and bolometers with semiconductor films.

In his paper, "Optimum parameters of a radiometer," A. N. Mikhailov examines the selection of the shape and size of the radiometer passband and the modulation frequency, the matching of the mixer to the intermediate frequency amplifier for a maximum sensitivity, and the distribution of gain between the high and low frequency radiometer units. It is shown that when steps against flicker noise are taken, it is possible to limit the gain of the radiometer high-frequency unit to 1500-2000.

In her paper, N. B. Mikhailova describes a correlation meter of weak noises and monochromatic signals in the range of 2-35 Mc.

In his report, entitled "A method of calibrating and checking field strength meters in the range of 12 kc to 25 Mc," V. S. Buzinov describes a reference field method provided by a frame antenna with known parameters. The electromagnetic field of the near zone (induction zone) is used. The value of the electromagnetic field for low frequencies in this instance is determined by dc formulas. From 10 Mc up it is, however, necessary to introduce frequency corrections. Design formulas are given and the errors of the method analyzed, showing that in the range of 12 kc to 10 Mc the largest possible error of calibration and checking of the field strength meters does not exceed ± 2.5%, and in the 10-24 Mc range ±5%.

In the paper of G. D. Burdun, E. B. Zal'tsman, and V. E. Poyarkova, "A method of precision measurements of dielectric parameters in the millimeter range," a standard device is described which measures dielectric parameters such as the permittivity and loss angle; an analysis of the sources of errors is made and optimum conditions of measurement specified. The Conference noted the practical value of this work.

In their paper entitled "Measurement of permittivity of rod samples at ultrahigh frequencies" Yu. Ya. Yurov and V. I. Vinokurov describe an apparatus for measuring permittivity of these samples in the centimeter range and examining the error of measurement. The input admittance of a short-circuited waveguide with the dielectric rod placed in it was calculated by two methods:

a) The field of the reflected wave was determined in conjunction with higher type fields by the method of characteristic vector functions; the input waveguide admittance was determined from the reflection coefficient thus found.

b) The principal field of the waveguide was considered, and for fields of a higher type it was assumed that telegraph equations hold in the case of a rod. The solution was obtained by means of the Lorentz lemma.

These calculation methods produced good agreement with experiments and other methods of measurement. Curves which provide a rapid finding of permittivity from the measurements were appended.

I. P. Gekker and V. I. Yur'ev reported on their work with a device for investigating the radiation spectrum in the millimeter and shorter wavelength ranges. The conference noted that the above device for physical investigation of the radiation spectra of Cerenkov, Doppler, etc., generated by relativistic electron beams, is simple and reliable in operation, provides wavelength measurements in the range of 12-0.5 mm, and is remote controlled, which is necessary in the presence of powerful x-ray radiations.

L. N. Bryanskii demonstrated in his two papers, "Precise measurement of the voltage standing-wave ratio by means of a phase-shifter and a probe" and "A method of checking waveguide measuring lines" that a voltage standing-wave-ratio meter, consisting of a phase-shifter and probe, can in many instances provide greater accuracy of measurement of the ratio than a measuring line.

Two basic methods of checking measuring lines were also examined: the element-by-element check and the check by means of standard loading. The Conference noted the necessity of developing a technique for testing coaxial lines and immediate adoption of the method and equipment for testing waveguide measuring lines.

In their paper, entitled "Direct reading instruments for recording matching characteristics," V. G. Dubenetskii and A. I. Konchitsa describe automatic, direct-reading, reflection and standing-wave-ratio meters in the

3 and 10 cm wavebands with two-coordinate recording of results. The characteristics of the basic elements of the waveguide and coaxial meters are given and the possible errors in measuring various reflection and standing-wave ratios are evaluated. The Conference noted the timely development of the instrument and the necessity of its completion in order to be able to decide on the advisability of its mass-production.

A. P. Kornilov in a paper entitled "Some technical applications of the phasometric methods for measuring nonelectrical quantities" described new radiotechnical methods of measuring and controlling nonelectrical values, a model of an electronic small-scale quartz extensometer which provides stable readings on samples 0.5 mm long at 1000°C, and an instrument for continuous checking of the diameter of thin (from 20 μ up) wire with automatic recording on a chart and automatic recording of deviations from the tolerances.

In their paper, "Experience in developing a microwave radiopyrometer," V. V. Kandyba, E. A. Kopilovich, G. P. Iosel'son, and P. A. Ivanov described their work in using radio emissions for measuring high temperatures. The Conference considered the work to be timely and recommended continuing it until it can be applied in practice.

I. S. Stepanov's paper, "Instruments for automatic production testing of long-distance communication equipment components" examines the principles of operation and data of the following instruments and devices, which provide either partial or completely automatic testing of several parameters under production conditions; the instruments include level indicators for the range of 0.2-300 kc and 0.3-10 Mc, an instrument for measuring permeability in the range of 50-1000 and a magnetic field strength of 1 oe, a semiautomatic bench for testing telephone transformers with respect to four parameters, a device for checking frequency converters, and a set for sorting resistors, inductors, and capacitors at 2.5 Mc. The Conference noted that the development of such instruments is of great practical value for the communication equipment industry; this equipment should be adopted in the plants.

Following M. V. Fomin's paper on "Problems in developing a set of UHF measuring instruments for radio relay lines" the participants of the conference expressed their wish to present a series of papers on individual instruments at the routine sessions of the A. S. Popov Society's section on radio measurements.

The paper of V. M. Shtein, V. I. Borisov, and D. A. Podberezin entitled "Utilization of pulse modulation for measuring time characteristics" proposes a method of measuring time characteristics based on the use of amplitude and phase pulse modulation. This method is preferable to the oscillographic one when time characteristics with a large range of instantaneous values are measured. The paper gave the test results of an instrument which uses the new method of measurements.

A. M. Chernushenko's paper "An apparatus for investigating high-frequency channels and delay systems by means of millimicrosecond pulses" deals with the separation of reflection measurements in delay systems and waveguides with reflections due to several irregularities along the high-frequency channel by means of the radiolocation method, which provides a time separation of reflections from various irregularities, thus making it possible to measure each reflection separately. In the equipment working on the basis of this method, a high-frequency oscillograph tube is used. The Conference decided to recommend that the State Committee on Electronics: a) use the materials presented in the paper for making commercial models of the equipment for investigating high-frequency channels and delay systems by means of millimicrosecond pulses; b) conduct experimental development work in designing special tubes for generating millimicrosecond pulses over the whole centimeter range.

In their paper, entitled "An instrument for visual observation of the transfer constant modulus of a four terminal network," P. I. Babkin and V. Ya. Lozovaya describe the development of a model of an instrument which makes it possible to observe on the screen of a cathode-ray tube the relation between the attenuation and frequency of a UHF signal and to compare it with a given value. The instrument consists of a klystron generator with mechanical tuning, a polarized attenuator, and an oscillographic unit. The time required for retuning the generator is 4 seconds.

In its resolutions on the papers read at this section of the conference, the section noted the importance and practical value of the reported works and recommended their publication in the periodic press.

The work of the section on radio measurements showed a growth, as compared with last year, in the number of papers in various spheres of radio measurement technology and the corresponding number of sets produced, including standard radio measuring instruments.

CONFERENCE ON THE PRODUCTION OF LABORATORY BALANCES

A scientific-technical conference, dealing with the prospects of the development of laboratory balance production, was held in Leningrad in September, 1959.

Papers by members of the D. I. Mendeleev All-Union Scientific Research Institute of Metrology (VNIIM), the All-Union Scientific Research Institute of Kinematics (VNIIK), the Gosmer plant, and other organizations were read at the conference.

A. I. Chinarev (VNIIK) dealt in his paper with the state of laboratory balance production in the Soviet Union and abroad.

N. A. Andreev dwelt on the development prospects of laboratory balance production in 1959-1965.

G. A. Gulin informed the conference of new analytical balances, and P. I. Timofeev, about special balances.

A paper on the proving of unequal arm balances of the analytical type was read by I. N. Nekrasov.

Chief Engineer of the Gosmetr plant M. A. Chernorez reported on the measures taken by the plant for improving the quality of the laboratory weighing instruments made by it.

N. N. Smirnova's (VNIIM) paper dealt with the use of balances for measuring and recording variable mass.

M. I. Tyutikova (VNIIM) dealt in her paper with the development of the methods and equipment required for checking standard and commercial weights of 1 g and smaller.

Over 20 people took part in the discussion.

The conference noted certain achievements in the production of high-precision scales with remote control, required in the most important spheres of national economy. The design and production of analytical and technical balances does not, however, as yet completely satisfy the growing requirements of modern technology

It is also necessary to improve the quality of laboratory balances produced by the Gosmetr plant. Despite the fact that this plant is the main supplier of laboratory balances, it does not possess sufficient space for the work in hand and lacks the modern equipment required for the production of high-quality precision balances.

The repair of laboratory balances and the supply of spare parts to the weighing-equipment repair shops is badly organized.

Nobody seems to be concerned with the training of engineers, technicians, and highly-qualified workers for the plants and workshops which are making or repairing laboratory balances.

The full conference resolution makes suggestions for eliminating the defects in developing, producing, and repairing laboratory balances and also in the training of personnel for the plants where laboratory balances are made.

The conference considered it necessary to call such conferences on laboratory balance production at least once every two years, and also to publish the conference proceedings.

THE COMMITTEE OF STANDARDS, MEASURES, AND MEASURING INSTRUMENTS

MEASURES AND MEASURING INSTRUMENTS APPROVED BY THE COMMITTEE AS THE RESULT OF STATE TESTS AND PASSED FOR USE IN THE USSR

(Registered in June and August, 1959)

Storage battery hydrometers with pipets, of the Moscow regional Sovnarkhoz . State register No. 1266-59.

Rack-mounted recording ammeters, trade mark N-386, of the Krasnodar Sovnarkhoz. State register No. 1267-59.

Rack-mounted recording voltmeters, trade mark N-386, of the Krasnodar Sovnarkhoz, State register No. 1268-59.

Mutual induction coils, trade mark R536, of the Kiev Sovnarkhoz. State register No. 1269-59.

Automatic, batch-weighing, unequal-arm scales, trade mark DN, of the Kiev Sovnarkhoz. State register No. 1270-59.

A truck dial weighbridge, trade mark ATs-10, of the Krasnodar Sovnarkhoz. State register No. 1271-59.

Audio and ultrasonic signal generators, trade mark ZG-11, of the Leningrad Sovnarkhoz. State register No. 1272-59.

DC bridges, trade mark P333, of the Krasnodar Sovnarkhoz. State register No. 1273-59.

Single dc bridges, trade mark MO-56, of the L'vov Sovnarkhoz. State register No. 1274-59.

Single-phase portable wattmeters, trade mark D-57, of the Kiev Sovnarkhoz, previously state registered under No. 1073-57, are supplemented by a wattmeter D-57 modification, providing a current range of 2.5-5 amp. State register No. 1073-57.